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LIFE HISTORY NOTES ON THE LITTLE TUNA, *EUTHYNNUS ALLETTERATUS*, FROM THE SOUTHEASTERN UNITED STATES.[1]

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ABSTRACT

The little tuna, *Euthynnus alletteratus* (Rafinesque), was the species most frequently brought in to the fishing dock at Pier 5, Miami, Florida, between September, 1952 and August, 1953. During this period, 1340 were examined, the period of greatest abundance being during the summer months. Data were collected on lengths, weights, frequency of occurrence, stomach contents and the reproductive cycle. Additional specimens were examined during the summer of 1951 between Cape Hatteras, North Carolina, and Cape Canaveral, Florida. Data are presented on the monthly and overall size distribution of fish taken, and growth is discussed on the basis of length frequencies. Male specimens of little tuna were found in a ripe condition from February through November, and ripe females occurred from January through November. Although the adults are typically inshore forms, occurring in less than 20 fathoms, the young are more common over deep water. Sex ratio and size at maturity are also discussed, and the food and feeding habits are reviewed.

INTRODUCTION

The little tuna, *Euthynnus alletteratus* (Rafinesque), is one of the commonest scombrids in the western North Atlantic (Rivas, 1951). Anderson (1954) stated that, during trolling surveys off the coast of the southeastern United States, the little tuna was the species most often caught, accounting for 40 per cent of the 247 fishes taken. In the collections of young fishes of the M/V OREGON in the Gulf of Mexico, it was the best represented of all scombrid species (Klawe and Shimada, 1959). Large schools of "extensive tonnage" of *E. allet-*

[1]Contribution No. 16, University of Delaware Marine Laboratories.

teratus were observed by Carlson (1952) off the southeastern United States.

The little tuna ranges from Ilha Victoria, Brazil, north to Bermuda and the Gulf of Maine, and throughout the Caribbean and to the northern and eastern Gulf of Mexico (Briggs, 1958). It is also taken in the Eastern Atlantic and Mediterranean (Postel, 1950). Ben-Tuvia (1953) recorded it from the Gulf of Aqaba, Red Sea, and Serventy (1941) reported it from Australian waters.

Despite its wide longitudinal range in the Western North Atlantic, the little tuna reaches its maximum concentration in tropical waters. It is caught throughout the year in Bermuda (Mowbray, 1956) and Florida (Fig. 4), as well as being abundant in certain parts of the Caribbean (Morice and Cadenat, 1952; Erdman, 1956). It occurs in most of these areas throughout the year, but is caught in the greatest numbers in the coastal regions during the summer months.

There has been widespread interest in this species, yet little is known of the life history of this and other Western North Atlantic scombrids, notwithstanding the substantial contributions of Postel (1950 *et seq.*) and Morice (1953) on the Eastern Atlantic populations (subspecies?). The commercial potential of the little tuna has been discussed by Chilton (1949) and Carlson (1952). Rivas (1951) stated that ". . . the flesh is good and of commercial importance through the West Indies . . .," and Mowbray (1956) noted that in Bermuda this species is good eating ". . . the smaller specimens being the best." In Australia, it is common and is utilized as a canned product (Serventy, 1941). The species is of commercial importance in the Eastern Atlantic (Postel, 1950), and *E. yaito* and *E. affinis* are the subject of fisheries throughout the Indo-Pacific region, particularly in Japanese waters.

The little tuna is well known to sportsmen in the Western Atlantic as an important sport fish, since its inshore habitat permits the small-boat enthusiast to fish at an expense considerably below the cost of fishing for the larger "deep-sea" species. It is also popular and very effective as a live bait for sailfish, and its importance as a natural food for this species has been noted by Voss (1953), who found that in southern Florida waters the little tuna occurred in 7.6 per cent of the stomachs of 241 sailfish, *Istiophorus albicans,* which contained food.

Methods and Materials

From 1952 to 1953, the authors had the opportunity to examine regularly sport fishes caught by anglers from charter boats based at

Pier 5, Miami, Florida. Between September 1952 and August 1953, 70 visits were made to this fishing dock at an average of about 1.5 times per week. Data collected included fork length from tip snout to the fork of the tail as suggested by Marr and Schaefer (1949), weight in ounces, sex and stage of maturity, stomach contents, and other pertinent observations.

During the summer of 1951, the junior author was engaged in exploratory fisheries research off the southeastern coast of the United States, between Cape Hatteras and Fort Pierce, Florida. The information gathered by us has been collated and is presented herein.

Acknowledgments

The authors wish to express their sincere appreciation to the many boat captains and to the dockmaster, Mr. Dan Daniels, of Pier 5, Miami, for making available their catches for examination. We wish to thank Prof. Luis René Rivas of the Department of Zoology, University of Miami, for suggesting the problem to the senior author, for his many valuable comments during the early phases of the field work at Pier 5, and for the table of criteria of gonad stages included in this paper. Gratitude is also due to Doris D. de Sylva, Dr. Victor G. Springer, and Messrs. Masood A. Burney and Ronald C. Eisler for valuable assistance in the collection of the field data, and to Drs. Julian D. Corrington and E. Morton Miller for making available the facilities of the University of Miami Department of Zoology. Appreciation is expressed to Mr. Carl B. Carlson, formerly of the U. S. Fish and Wildlife Service, and to Mr. Sterling Harris of the Blue Channel Corporation of Beaufort, South Carolina.

Systematics

Fraser-Brunner (1949) recognized two species of the genus *Euthynnus* which were placed in five subspecies: *E. affinis affinis* (Cantor), from the Indo-Pacific; *E. affinis yaito* Kishinouye, from Japan, Hawaii and "Pacific Islands"; *E. affinis lineatus* Kishinouye, from the Eastern Pacific; *E. alletteratus alletteratus* (Rafinesque) from the Western Atlantic and Mediterranean; and *E. alletteratus aurolitoralis* Fraser-Brunner from Ghana. In a subsequent paper (1950), he expanded the genus to include *Euthynnus* (*Katsuwonus*) *pelamis* (Linnaeus).

Various authors have regarded *E. alletteratus* as occurring in the Pacific, but recent workers tend to confine this species to the Atlantic.

Godsil (1954a, b) recognized three species, *yaito, alletteratus,* and *lineatus,* but indicated that meristic and proportional differences among the species were relative, and that the superficial resemblances were not necessarily corroborated by internal anatomical differences. That *lineatus* is a valid species was clearly shown, but his findings indicate that *alletteratus* of the Atlantic and *yaito* of the Indo-Pacific, although treated by him as species, may prove to be merely ends of a cline when further studies are undertaken throughout the range of the two species. If this were true, *E. alletteratus* would have nearly a world-wide circumtropical and circumtemperate distribution. The characters presently used to separate *yaito* and *alletteratus,* such as the presence of vomerine teeth, number of gill rakers, and proportional measurements, are far from trenchant.

Results

The data presented herein cannot be interpreted as a true picture of either abundance or availability, for, in a sport fishery where log books of the catches are not maintained, it is almost impossible to obtain catch per unit of effort. Thus, availability reflects weather conditions, day of the week, volume of tourist trade, and the like. Superimposed upon this is the fact that anglers often fish for larger species such as sailfish and marlin in which a large bait is required, with the result that the effort for smaller species is reduced even though the fish are present.

Little tuna from Pier 5 comprise only the upper size range of the species (above 272 mm). Fish larger than 25 pounds are seldom taken, and fish over 15 pounds are not common. Most are taken by trolling with a small- to moderate-sized feather jigs, spoons, or strip bait. The latter consists of a strip of fish belly or skin attached to a hook or feather jig. The size range generally landed is from about 500 to 750 mm fork length, with a corresponding weight range of from about 4 to 14 pounds (Fig. 1). Only a few very large or very small fish enter the catch. With respect to this illustration, it is seen that fish over 620 mm are predominantly males, possibly suggesting either a differential growth rate or a mortality at this point between the sexes. Ommanney (1953) noted the males of *E. affinis* reached a larger size than the females. Postel (1954b; 1955) found that there were no marked differences in the maximum size of the sexes attained in little tuna taken throughout the year in the Eastern Atlantic. He presented a graph in his earlier paper showing the size distribution of the sexes

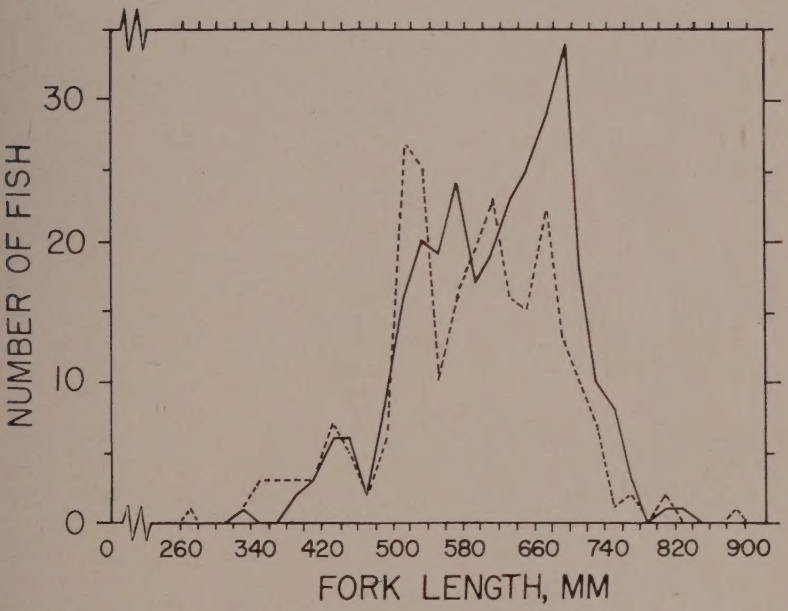

FIGURE 1. Frequency distribution of male and female little tuna caught by anglers off Miami, Florida, September, 1952 to August, 1953. Solid line represents males (N=295); dashed line represents females (N=242).

from Cape Verde which did not agree with his original data, but which, if examined, indicate that males reach a somewhat larger size than the females.

The size range of the little tuna caught along the coast of North Carolina, South Carolina, and Florida in July, 1951, is roughly comparable to those caught by charter boats based at Pier 5, Miami, from 1952 to 1953 (Fig. 2). However, while the Pier 5 samples show a more even distribution of sizes, the curve representing those taken in 1951 is markedly leptokurtic. This suggests a strong gear selectivity, possibly due to the use of only certain range of hook sizes on the jigs. Carlson (1952) explained that this selectivity is possibly due to the loss of smaller fish because of their more tender mouths from which the hook easily pulls free. Morever, the Pier 5 samples were taken by a wide variety of baits and artificial lures, and the angler usually tends to play the fish more, so that the hook has less chance to tear the mouth.

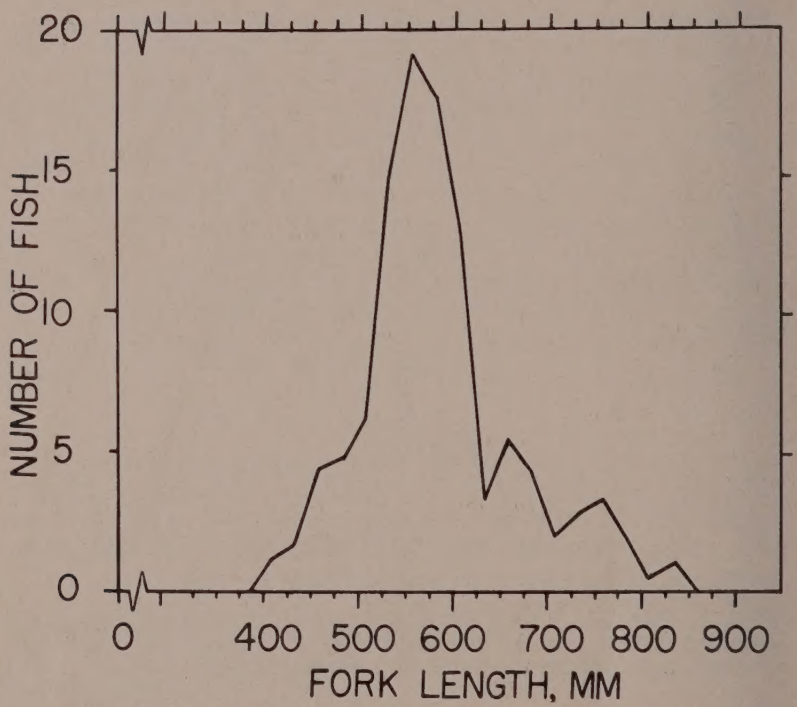

FIGURE 2. Length-frequency distribution of 217 little tuna caught by commercial trolling gear between North Carolina and northern Florida, July, 1951.

AVAILABILITY AND ECOLOGY

The relative abundance of little tuna in angler catches at Pier 5 was sampled on selected days from 1952 to 1953 (Table 1; Fig. 4). This is one of the commonest scombrids brought in to the fishing docks, and of 70 trips made, the little tuna was noted 65 times, or on about 93 per cent of the trips. Other species landed at these docks include the king mackerel, *Scomberomorus cavalla* (Cuvier), dolphin, *Coryphaena hippurus* (Linnaeus), great barracuda, *Sphyraena barracuda* (Walbaum), sailfish, amberjack, *Seriola dumerili* (Risso), blackfin tuna, *Thunnus atlanticus* (Lesson), and skipjack tuna (oceanic bonito), *Euthynnus pelamis* (Linnaeus), in approximate order of abundance, although none is consistently present in the angler catch. Of the 1340 little tuna recorded from Pier 5, 1165, or about

87 per cent, occurred from March through August, with a peak in July of 481, about 36 per cent of the total sample.

There is evidence of a general drift of little tuna out of the Miami region toward the south during the winter. Large aggregations of this species are noted by shrimp fishermen in the vicinity of Tortugas during the winter months, which do not seem to be present the remainder of the year. Conversely, the little tuna occurs further northward along the Atlantic coast during the summer months (Fig. 3). These data, based on material collected by the U. S. Fish and Wildlife research vessel T. N. GILL, also suggest that there may be a slight inshore drift during the warmer months. Serventy (1941) noted a summer, coastwise migration of little tuna in Australia toward the south.

TABLE 1

RELATIVE ABUNDANCE OF LITTLE TUNA OBSERVED IN ANGLERS' CATCHES AT PIER 5, MIAMI, FLORIDA, FROM SEPTEMBER, 1952 TO AUGUST, 1953

Month	No. fish examined	No. sampling trips made to Pier 5	No. per trip
Sept.	4	1	4
Oct.	29	6	5
Nov.	40	9	4
Dec.	19	4	5
Jan.	51	5	10
Feb.	29	6	5
Mar.	69	8	9
Apr.	195	8	24
May	49	5	10
June	481	6	80
July	260	8	32
Aug.	114	4	28
Total	1,340	70	

Average no. per trip = 19
Average no. per month = 112

The apparently large day-to-day fluctuations of the little tuna are well known to the charterboatmen. Thus, large schools which were taken by anglers in the middle of June shortly disappeared and hence reappeared, to a lesser extent, in July (Fig. 4). It is at this time that the peak of the spawning season occurs, and it is possible that these peaks in the catch represent spawning aggregations.

Along the Atlantic coast, most little tuna are caught in "green water," that is, they seldom are taken in the "blue water," or slope

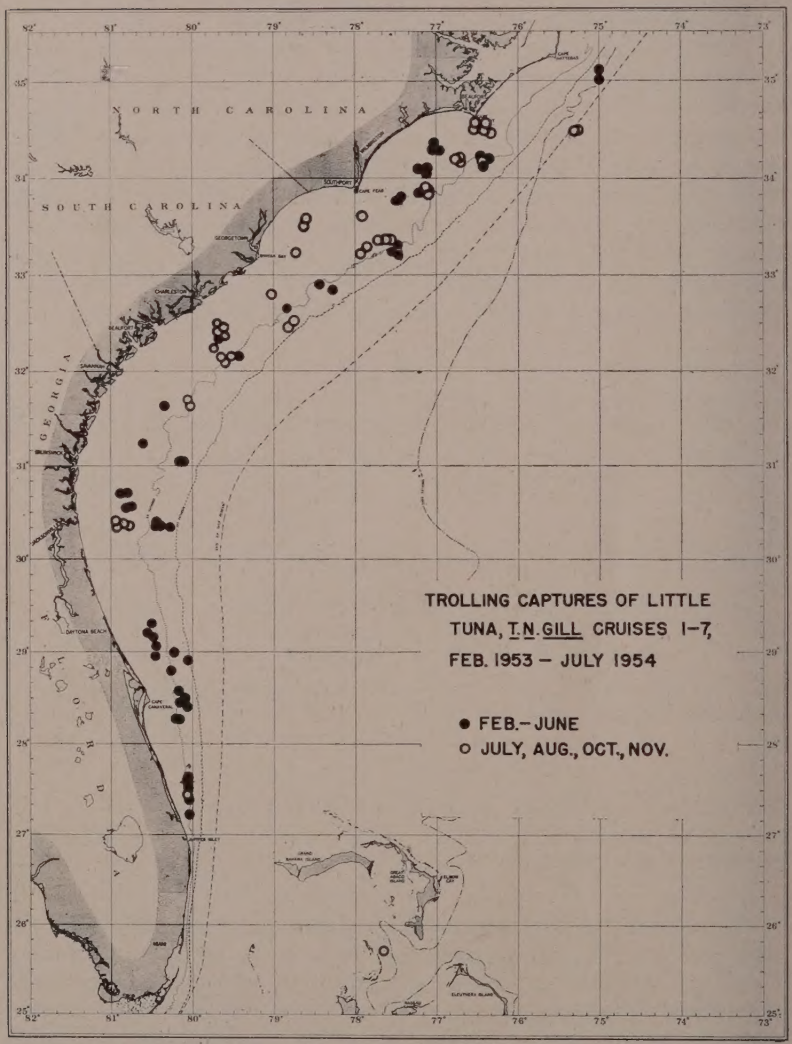

FIGURE 3. Seasonal distribution of little tuna off the southeastern United States. Data compiled from cruise reports of the U.S. Fish and Wildlife Service vessel *T. N. GILL*.

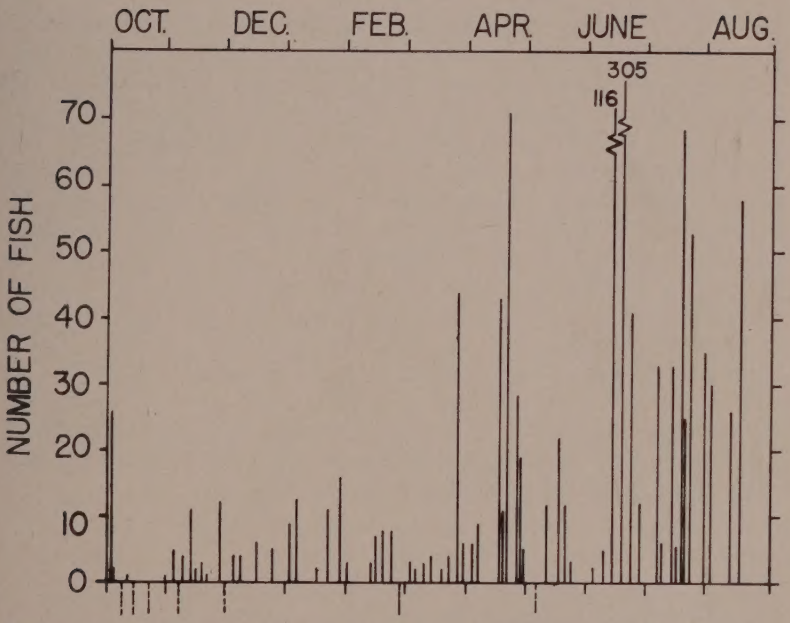

FIGURE 4. Frequency of relative occurrence of little tuna caught by anglers off Miami, Florida, September, 1952 to August, 1953. Dotted, vertical line below horizontal axis indicates days sampled when no little tuna were caught.

water, of the Florida Current. The inshore, more turbid waters are thus more typical habitat for the species. Morice and Cadenat (1952) noted that little tuna were found in turbid, inshore waters of Guadelupe. Little tuna seldom enter very shallow waters, but in some West African rivers they are occasionally taken in seines in large numbers. Postel (1950) believed that this was part of a seasonal migratory pattern.

Although Springer and Bullis (1956) collected both young and adults of the little tuna over deep waters in the Gulf of Mexico, the adult is generally confined to shoal waters, and it is more of an inshore species than other small tunas such as the blackfin tuna and the oceanic bonito. Whiteleather and Brown (1945) observed that the little tuna seemed to be definitely a continental fish in the region of Trinidad, Tobago, and British Guiana. Springer and Bullis (*op. cit.*) listed 22 catch localities for the little tuna in the Gulf of Mexico made

by the M/V OREGON using various gears. Of these, six are young specimens caught by trolling, handlines, pole and lift nets, or shrimp trawls. The adults occurred over water ranging from 5 to 600 fathoms, with a mean depth of about 80 fathoms. However, the *median* depth value is only 18.5 fathoms, thus indicating that for these data, while the little tuna does venture far out over deep water, it is more likely to be taken in shoal water. Anderson (1954) stated that along the coast of the southeastern United States, with few exceptions, little tuna were taken by trolling within the 20-fathom line. Mather and Day (1954), in a series of extensive observations over deep water in the tropical Atlantic, reported only two little tuna taken, both of which occurred in relatively shallow water. In the Eastern Atlantic, Postel (1950) reported that little tuna occurred to the 100-meter isobath. Godsil (1954) discussed the apparent restriction of *E. yaito* to within the 20- to 30-fathom contour around the Hawaiian Islands, and Williams (1956) noted that schools of *E. affinis* seemed to be restricted to within the 100-fathom curve off British East Africa.

TABLE 2

LENGTH FREQUENCIES OF 827 LITTLE TUNA IN ANGLERS' CATCHES AT PIER 5, MIAMI, FLORIDA, FROM SEPTEMBER, 1952 TO AUGUST, 1953

Class interval, fork length, mm	1952 Sept.	Oct.	Nov.	Dec.	1953 Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Tot.
240-279	—	3	—	—	—	—	—	—	—	—	—	—	3
280-319	1	4	2	—	—	—	—	—	—	—	—	—	7
320-359	1	16	2	1	—	—	1	—	—	—	—	—	21
360-399	—	1	2	5	1	—	1	1	—	4	2	3	20
400-439	1	—	5	1	1	3	—	1	—	3	15	2	32
440-479	—	—	1	—	2	2	2	1	—	1	18	6	33
480-519	—	—	5	4	13	1	4	20	14	10	8	5	84
520-559	1	—	4	2	7	3	3	23	8	27	26	22	126
560-599	—	—	1	—	9	10	7	33	2	16	15	10	103
600-639	—	—	—	2	7	4	14	43	6	24	14	14	128
640-679	—	1	1	1	1	2	14	44	5	23	26	10	128
680-719	—	2	5	—	2	2	10	20	9	15	18	6	89
720-759	—	1	3	2	4	1	6	8	1	6	7	3	42
760-799	—	—	—	—	—	—	2	—	1	1	1	1	6
800-839	—	—	—	—	—	—	—	1	—	1	1	1	4
840-879	—	—	—	—	—	—	—	—	—	1	—	—	1
Total	4	28	31	18	47	28	64	195	46	132	151	83	827

Length Frequencies

Fork lengths of 827 male and female little tuna examined at Pier 5 are grouped in 40-mm intervals by months (Table 2; Fig. 5). It is seen that during September and October, smaller fish are available, the smallest encountered during this study being 272 mm. taken on October 4, 1952. A specimen 207 mm in fork length was taken on spinning tackle off Horn Island, Mississippi, on July 4, 1958. Klawe and Shimada (1959) presented valuable data on the size distribution of 679 young specimens of little tuna in the Gulf of Mexico. Specimens ranging from 3.5 to 174 mm were taken from June to September, mostly in the northern Gulf of Mexico, and Bullis (1955) discussed the attraction of little tuna to night lights in the Gulf of Mexico on July 19, 1954, of which 96 were collected which were 20 to 31 mm in fork length.

A slight but smooth progression in minimum size is seen in the 240-mm group in October to the 400-mm group in February, the modal growth over four months being suggested by the difference (Table 2; Fig. 5). There is little evidence, however, of distinct modal progression, such as that found in the sailfish (de Sylva, 1957), probably reflecting the long spawning period and thus making analysis according to the method of Petersen (1893) very difficult. Although the sample size is small, in October a distinct mode occurs in Figure 5 at 320 mm, another at 600 and 640 mm in April, and a third persistent mode from June to August at 520 mm.

Postel (1950) was able to construct a growth curve for the little tuna from West Africa on the basis of length frequencies. He stated that growth could not be studied by the use of scales or vertebrae. In a later paper (1956), he presented figures slightly different from those in his 1950 paper, although both sets of data are similar. Using the data presented in Table 2, plus the figures of Morice and Cadenat (1952) and Klawe and Shimada (1959), a composite picture of the growth of the genus *Euthynnus* is suggested (Fig. 6). If it is possible to assign any degree of accuracy to the assessment of age and growth on the basis of these length frequencies, it would seem that the angler catch of little tuna from Pier 5 is composed essentially of fish from three to four years of age (Fig. 1).

Data are also included on the growth of *E. affinis* from East Africa (Ommanney, 1953) for comparative purposes. As with most tuna-like fishes, the growth is rapid for the first part of their life, decreasing somewhat at maturity. There is little evidence either from our data or

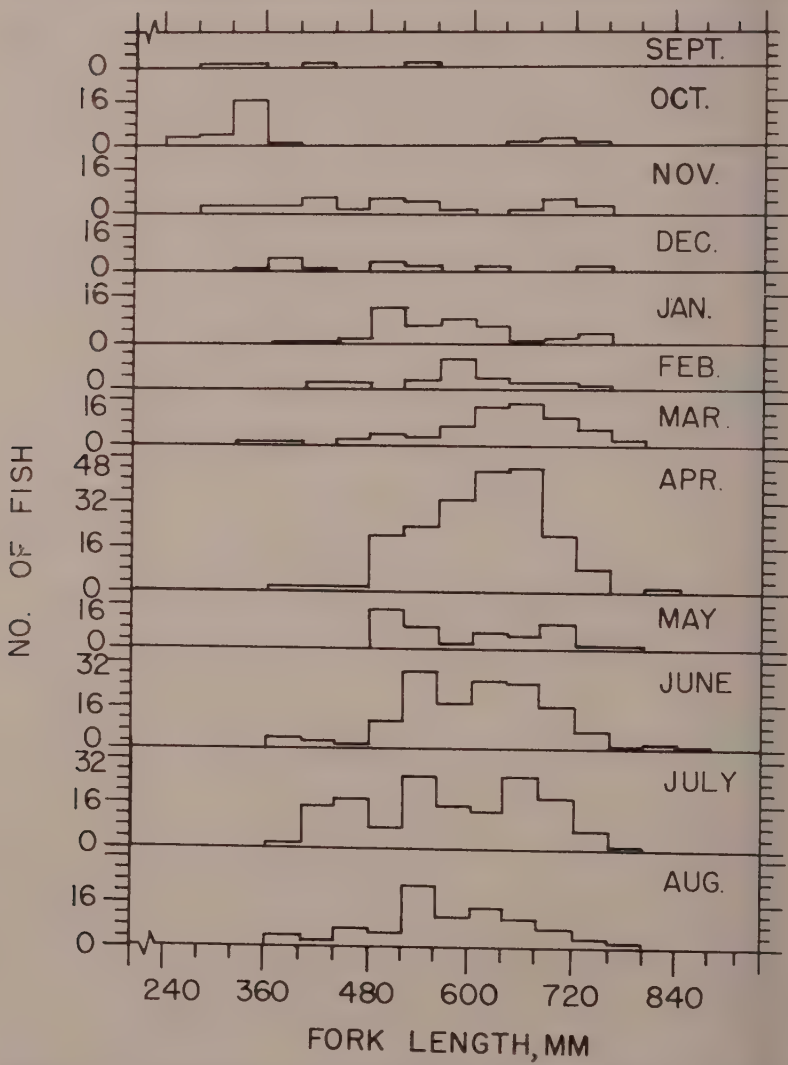

FIGURE 5. Length frequencies of 827 little tuna caught off Miami, Florida, September, 1952 to August, 1953. Data do not include 292 specimens measuring from about 600 to 750 mm which were caught in April, but which could not be measured.

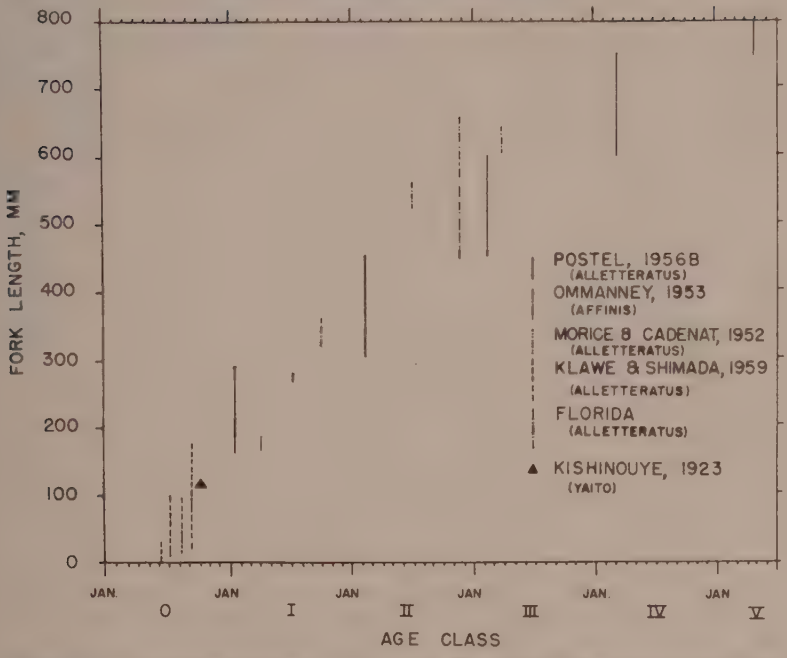

FIGURE 6. Length frequencies of the genus *Euthynnus* based upon field data and literature records.

those presented by Postel (1950 *et seq.*), or Ommanney (1953) that this genus grows older than five years. The growth curves presented by various workers for different species and different areas agree markedly, and the differences that do occur seem to be among the older fish.

REPRODUCTION

Off the southeastern coast of Florida the little tuna does not have a well-defined spawning season. Observations by the junior author between Cape Hatteras and Fort Pierce, Florida, from June to August 1951, indicate that reproductive activity was in a well-developed state. Eggs were usually discernible macroscopically, and on many occasions milt was freely running from the male. On July 13 three females were captured which appeared to have recently spawned. This was observed about 25 miles southeast of Charleston, South Carolina, and was often noted throughout the summer. It was also observed that the size of

the gonads, particularly the ovaries, were larger during the summer months. Erdman (1956) stated that ripe males are found in Puerto Rico in June and July, and Kishinouye (1923) noted that *E. yaito* spawns in May in Formosa. In Martinique, Maurice and Cadenat (1952) noted the presence of young from mid-April onwards.

TABLE 3

CRITERIA FOR STAGES OF SEXUAL MATURITY IN THE LITTLE TUNA

Males	
Stage 1	White but slender. Blood vessels on surface not developed. Firm to the touch.
Stage 2	Thicker than stage 1. Blood vessels developed on surface, but milt does not flow out when spermatic canals are pressed.
Stage 3	Thicker than stage 2. Blood vessels further developed. Milt flows when spermatic ducts are pressed.
Females	
Stage 1	The ovaries are thin and the blood vessels are not yet developed on the surface which is smooth. Ova do not show as distinct grains. Sometimes difficult to distinguish from testes.
Stage 2	Thicker than 1. Development of blood vessels perceptible on surface which shows transverse folds.
Stage 3	Thicker than 2. Folds further developed on the surface. Purplish stripes appear along the folds. Ova showing as distinct grains, at least under magnification.
Stage 4	Thickness further increased. Surface distended. More numerous purplish stripes. Eggs distinctly visible.
Stage 5	Ovary spent. Most large eggs extended from ovary, a few adhering to walls. Slimy consistency to ovary walls.

Observations were made by the senior author on little tuna from Pier 5 using the criteria adopted in Table 3. Ripe males were present 10 months of the year from February through November, and ripe females occurred during eleven months, their absence being noted only in December (Table 4). However, in the case of both males and females, since samples were often small it is possible that ripe individuals occurred in the population during the winter even though they did not appear in the angler catch.

Although indications of spawning are seen most of the year, a peak is observed in June followed by a slight decrease, which is indicated by the presence of spent fish in the catch. The percentage of ripe males (stage 3) changes rather abruptly from 11.8 to 88.9 per cent between March and May. According to the average isotherm value in this

TABLE 4

MONTHLY PERCENTAGE OF 523 LITTLE TUNA FROM PIER 5, MIAMI, FLORIDA, FROM SEPTEMBER, 1952, TO AUGUST, 1953, WHICH EXHIBITED VARIOUS STAGES OF REPRODUCTIVE ACTIVITY. NUMBER OF INDIVIDUALS REPRESENTED IN PARENTHESES

	MALES							FEMALES										
	1		2		3		Total	1		2		3		4		Spent		Total
1952																		
Sept.	—	—	—	—	—	—	0	—	—	100.2	(2)	—	—	—	—	—	—	2
Oct.	75.0	(3)	—	—	25.0	(1)	4	20.1	(1)	—	—	—	—	80.0	(4)	—	—	5
Nov.	72.7	(8)	9.1	(1)	18.2	(2)	11	—	—	—	—	75.0	(3)	25.0	(1)	—	—	4
Dec.	100.0	(3)	—	—	—	—	3	—	—	50.0	(1)	50.0	(1)	—	—	—	—	2
1953																		
Jan.	88.2	(15)	11.8	(2)	—	—	17	—	—	35.0	(7)	30.0	(6)	5.0	(1)	30.0	(6)	20
Feb.	66.7	(10)	20.0	(3)	13.3	(2)	15	—	—	25.0	(2)	—	—	37.5	(3)	37.5	(3)	8
Mar.	64.7	(11)	23.5	(4)	11.8	(2)	17	5.0	(1)	60.0	(12)	25.0	(5)	5.0	(1)	5.0	(1)	20
Apr.	33.3	(25)	9.3	(7)	57.4	(43)	75	3.4	(2)	45.7	(27)	28.8	(17)	22.1	(13)	—	—	59
May	11.1	(2)	—	—	88.9	(16)	18	4.3	(1)	13.0	(3)	13.4	(4)	65.3	(15)	—	—	23
June	2.3	(1)	—	—	97.7	(42)	43	—	—	—	—	3.0	(1)	97.0	(32)	—	—	33
July	9.2	(6)	—	—	90.8	(59)	65	6.1	(3)	2.0	(1)	8.2	(4)	75.5	(37)	8.2	(4)	49
Aug.	23.5	(4)	—	—	76.5	(13)	17	23.1	(3)	—	—	—	—	76.9	(10)	—	—	13
Total	—	(88)	—	(17)	—	(180)	285	—	(11)	—	(55)	—	(41)	—	(117)	—	(14)	238
Mean	30.9	(7.3)	6.0	(1.4)	63.1	(15.0)	—	4.6	(9.2)	23.1	(4.6)	17.2	(3.4)	49.2	(9.8)	5.9	(1.2)	19.7

region given by Fuglister (1947) this substantial increase in the percentage of ripe males corresponds to an increase in average water temperatures from 74 to about 79° F.

The first ripe male was collected on February 19, 1953; it was 725 mm and weighed 12¼ pounds. The absence of stage-2 males between May and October, despite the presence of stage-1 males during nearly every month, is puzzling, although it may possibly reflect the difficulty of distinguishing macroscopically between late phases of one stage and early phases of the subsequent one. The frequency and duration of spawning of an individual fish is not known, but it is probably long, since there is such a small percentage of sexually inactive males present in the catch throughout the spawning season.

Indications of spawning in the female roughly parallel that of the

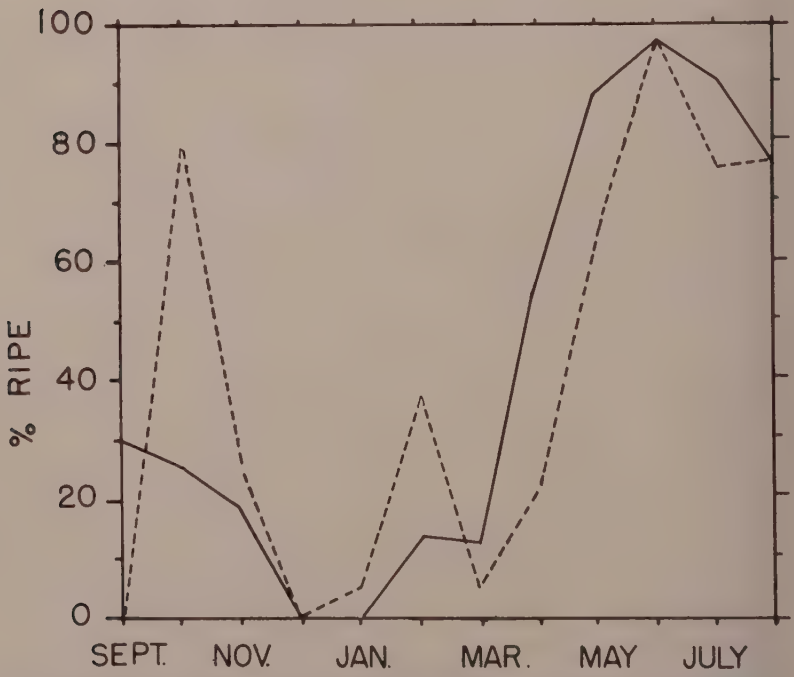

FIGURE 7. Spawning season of little tuna off Miami, Florida, as indicated by percentage of ripe fish. Solid line represents males (N=285); dashed line represents females (N=238).

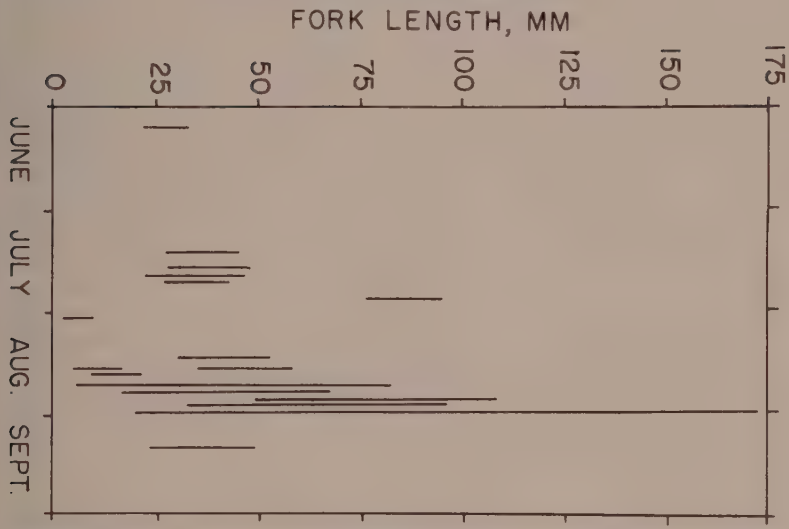

FIGURE 8. Range of fork lengths of 679 little tuna from the Gulf of Mexico. Data compiled from Klawe and Shimada (1959).

male in duration and occurrence, although spent females occurred as late as March and were also recorded in February and July. Peak spawning, as inferred from gonad examination, occurs from April through August, particularly in July, and a few fish contained ripe eggs throughout the year. As in the male there is a sudden change in the percentage of ripe females in the catch, from 5 per cent in March to about 65 per cent in May. A distinct lag in the ripening of the females behind the males can be seen in Figure 7. The small percentage of ripe females shown in the graph for October is probably due to the small sample for this month; similarly, a small sample in December and February may affect the results. However, for the majority of specimens in the sample, the spawning pattern is seen to portray an extended season, beginning rather abruptly in March and continuing up to about November, with the males ripening somewhat earlier, but with the females remaining in spawning condition later in the year.

Data presented by Klawe and Shimada (1959) on the date of capture of 679 juvenile little tuna in the Gulf of Mexico are presented in Figure 8. These were taken from early June through mid-September, although the majority of the specimens were captured from mid-July

to the end of August. The occurrence of several groups of very small fish throughout the summer suggests a protracted spawning over this period.

Anderson *et al.* (1956 *et seq.*) reported on the capture of 58 female and 40 male little tuna by the M/V T. N. GILL. These were captured off the southeastern coast of the United States during February, March, April, May and October of 1953 and 1954. Most specimens examined during these cruises were not in a spawning condition, although many were approaching ripeness in the May samples. Individuals having spent gonads were taken in July, October and February. During the present studies, ripe fish were taken most of the year, and the apparent difference in extent of spawning season based on Anderson's data and our data may reflect either separate populations showing different spawning characteristics, or a shorter spawning season for those tuna north of the temperature break at Cape Canaveral depicted by Fuglister (1947).

That spawning populations of the little tuna may occur is further suggested in the absence of any individuals in a ripening or ripe condition from Delaware and Maryland waters during August and September, 1959. Twenty-three females were examined, all of which were in a spent condition, thus suggesting earlier spawning in this area than in more southerly waters.

The only previous studies on the spawning of *E. alletteratus* in the Atlantic are those by Postel (1950 *et seq.*) and Frade and Postel (1955). In this series of papers dealing with the reproductive habits, Postel (1950) presented comprehensive data on period of spawning, stating that young fish (387-562 mm) remain ripe most of the year, while adults (712-937 mm) are ripe from June to August, development beginning in April and decreasing in activity toward the end of the summer.

Histological studies by Frade and Postel *(op. cit.)* showed that spermatogenesis was generalized at the beginning of March, and by July the spermatic ducts were empty, although young individuals still exhibited spermatogenesis. Similar studies on the ovary confirmed their earlier diagnosis that spawning in the adults occurred from June to September and October. This period is considerably shorter than that found off Florida, possibly due to the comparatively greater mean monthly temperature range off Cape Verde where Postel's samples were taken. The mean annual range is about 6°C off Florida, whereas it is about 12°C off West Africa. In the latter region, from May to

July there is a mean increase of from about 18° to 27°C, and possibly the relatively low water temperature before May retards gonadal ripening.

The spawning habits of *Euthynnus alletteratus* from the Indo-Pacific have been reported by Delsman (1931) (as *"Thynnus thunnina"),* Delsman and Hardenberg (1934), and DeJong (1940). The present study suggests that in the Western Atlantic fractional spawning occurs over a long period, and this has also been noted by Postel (1950) in the Eastern Atlantic specimens. However, the study of DeJong (1940) indicates that on the basis of length frequencies of ova, in the Java Sea *E. alletteratus* is not a distinctly fractional spawner, such as was found by Kisselevitch (1923) in the Caspian herring, but that the spawning batch of eggs in the ovary are divided into three frequency polygons. In this case, the data suggest that rather than a continually maturing hatch of eggs, two of the oöcyte groups mature during a season, so that this results in two spawning peaks for the season. Thus, this, when spread over a spawning season, may give the illusion of fractional spawning of each individual.

Ommanney (1953) found a bimodal season in the spawning of *E. affinis* in East Africa which occurred in September and October and again in March and April; however, this may be possibly due to his lack of samples for intervening months. Williams (1956), working in the same area, found ripe males of *E. affinis* from January through June and ripe females from January to April, in July and August, and in November and December. March and April appeared to be the peak spawning months, and spent, recovering females were recorded from March through August.

Delsman and Hardenberg (1934) described the spawning and the eggs and larvae of the little tuna in the Malayan region, stating that the eggs are pelagic, and of a diameter of 0.9 mm. Postel (1955) observed that a 79 cm fish (approximately 16 pounds) contained 1,750,000 eggs, and noted that they were pelagic.

Sex Ratio

Table 5 indicates the number and percentage of male and female little tuna caught by trolling gear during June, 1951 between Cape Hatteras and Fort Pierce, Florida, over a period of 21 fishing days. Possibly due to the small numbers caught on certain days and also to the possibility that more than one population may have entered the catch there are large discrepancies in the daily sex ratios; nevertheless,

TABLE 5.

SEX RATIO OF LITTLE TUNA DURING 21 EXPLORATORY FISHING DAYS BETWEEN FORT PIERCE, FLORIDA, AND CAPE HATTERAS, NORTH CAROLINA, JULY, 1951

	Females		Males		
Date	Number	Percent	Number	Percent	Total Number
3	8	61.6	5	38.4	13
4	4	66.7	2	33.3	6
6	3	75.0	1	25.0	4
8	4	33.4	8	66.6	12
10	2	50.0	2	50.0	4
11	3	17.6	14	82.4	17
12	1	20.0	4	80.0	5
13	3	100.0	0	—	3
17	4	57.2	3	42.8	7
18	21	53.9	18	46.1	39
19	7	38.8	11	61.2	18
20	1	25.0	3	75.0	4
22	5	35.7	9	64.3	14
24	6	50.0	6	50.0	12
25	4	57.0	3	42.8	7
26	8	53.3	7	46.7	15
27	7	63.7	4	36.3	11
28	1	16.6	5	83.4	6
29	2	40.0	3	60.0	5
30	7	58.3	5	41.7	12
31	5	38.4	8	61.6	13
Total	106	46.7	121	53.3	227

TABLE 6.

SEX RATIO OF LITTLE TUNA FROM PIER 5, 1952 TO 1953.

	Females		Males		
Month	Number	Percent	Number	Percent	Total Number
Sept.	2	50.0	1	50.0	3
Oct.	7	63.6	4	36.4	11
Nov.	4	23.5	13	76.5	17
Dec.	2	40.0	3	60.0	5
Jan.	20	54.1	17	45.9	37
Feb.	8	34.8	15	65.2	23
Mar.	20	54.1	17	45.9	37
Apr.	59	44.0	75	56.0	134
May	24	55.8	19	44.2	43
June	33	43.4	43	56.6	76
July	49	43.0	65	57.0	114
Aug.	33	66.0	17	34.0	50
Total	289	52.5	261	47.5	550

when the total number is examined, it is evident that the 53:47 ratio of males and females does not differ significantly from the expected 1:1 ratio (chi-square = 0.92, $P > .10$).

Observations on the sex ratio of 550 little tuna examined throughout the year at Pier 5, Miami, (Table 6) indicate a surprising closeness to the ratio observed during the summer of 1951 (Table 5). The latter observations revealed 53.3 per cent males to 46.7 per cent females, whereas the Pier-5 studies showed 52.5 per cent males to 47.5 per cent females. Again, the chi-square value of 1.43 is not significant ($P > .10$). The sex ratio when examined throughout the year does not show any marked variation from month to month, although slight deviations are probably due to small samples available.

Postel (1950; 1954) observed that the sex ratio of Eastern Atlantic little tuna was equal. Some slight monthly fluctuations were noticeable, but these appeared to be random.

Size at Maturity

The percentage of ripe fish by size is plotted by month in Figure 9. Besides being few in number, particularly for small fish, since these data deal distinctly with the larger, angler-caught fish, data concerning the sexual development of the smaller specimens are practically non-existent. The smallest fish observed at the docks was ripe (a 272 mm female); most fish in the sample did not reflect spawning until they had reached a length of 350 mm. Females less than 380 mm were ripe from August to October, but only three males less than 400 mm were taken during the entire year. Two of these, taken in August, were ripe, and it would seem that females longer than 360 mm were ripe, while males longer than 400 mm were ripe. Similar conclusions were reached by Postel (1950; 1954c) for the Eastern Atlantic little tuna. He considered that maturity was attained when the gonosomatic ratio reached 3 to 4 per cent, at which time the sexual products could be expressed from the body with slight pressure on the body walls. He found that males matured at a fork length of 401 mm and a weight of 1060 grams, while females matured at a length of 386 mm and a weight of 900 grams, at "between one and two years." Ommanney (1953) did not detect any mature specimens of *E. affinis* smaller than 500 mm, although samples of fish smaller than 400 mm were not available to him. He suggested that *affinis* probably spawns in its third year (i.e., age III), this representing a later age at maturity than for *alletteratus*.

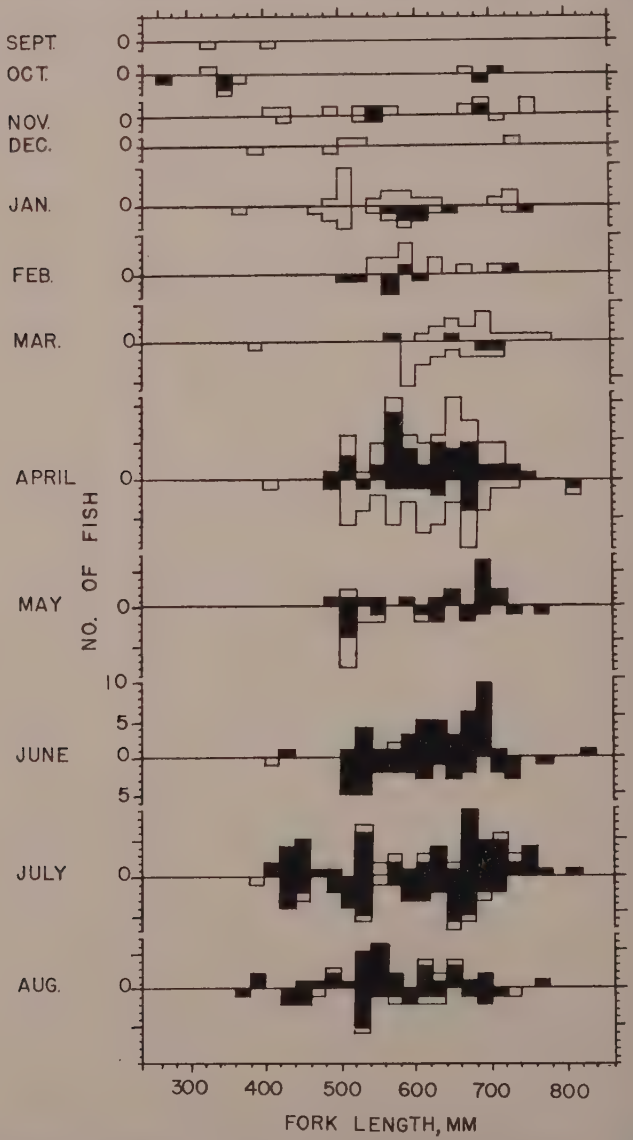

FIGURE 9. Size at maturity of little tuna caught off Miami, Florida, September, 1952 to August, 1953. Open bars represent non-ripe fish; solid bars indicate ripe fish. Males are above horizontal axes; females are below.

Length-Weight Relationship

The graph of this relationship is presented in Figure 10, which represents a total of 115 little tuna examined at Pier 5 from September, 1952 to August, 1953. The relationship is expressed by the formula $W = 6.73 \times 10^{-3} L^{3.10}$ where W = weight in ounces and L = fork length in millimeters. It is noteworthy to compare this value with that

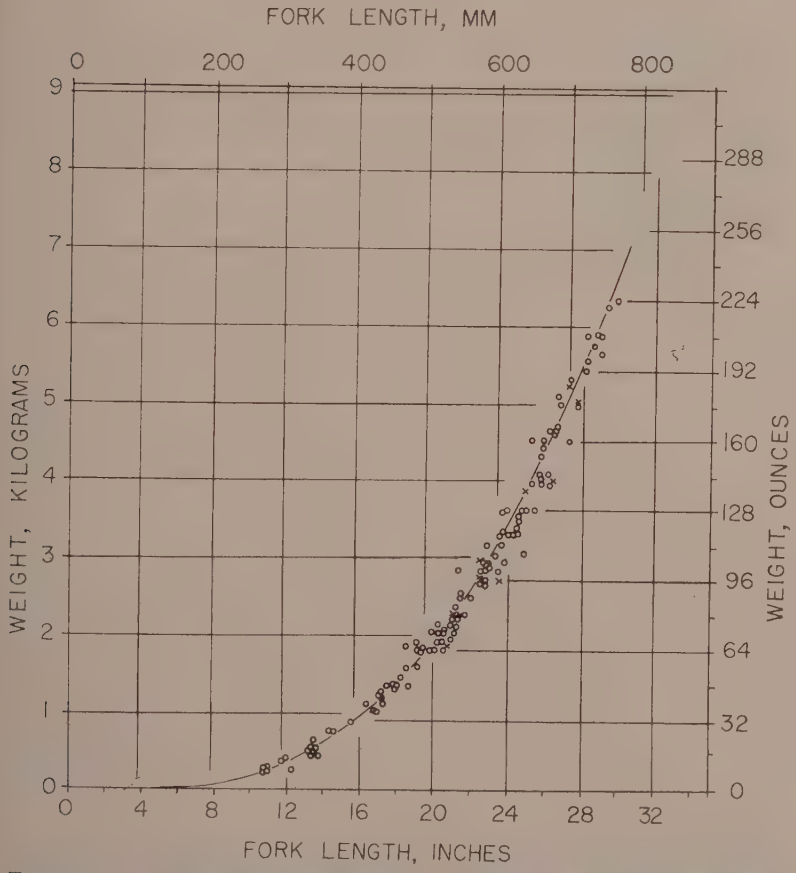

Figure 10. Length-weight relationship of 115 little tuna caught off Miami, Florida, September, 1952 to August, 1953, sexes combined. Crosses represent data of Morrow (1954) from East Africa.

noted for the Eastern Atlantic little tuna, *E. alletteratus aurolitoralis,* given by Morrow (1954) as $W = 1.63 \times 10^{-6} L^{3.16}$; despite the few data available to him, it is seen that the exponent values are extremely close together (see Figure 10). It is also of interest to note the high value of n (in the equation $W = CL^n$), indicative of typical tuna-like chunkiness. Postel (1950) presented a weight-length curve for little tuna taken off Cape Verde, and arrived at a weight-length curve of $P = 12.7\ L^3$, where P is in kilograms and L in in meters.

A Review of the Food and Feeding Habits of *Euthynnus*

Like most scombrid fishes the little tuna is largely carnivorous. In many cases the fish have been observed by the junior author to feed on large schools of clupeoid fishes. In such circumstances the presence of feeding fish is detectable to the fishermen by the action of diving birds. Direct observation on the manner of feeding is seldom possible with these rather timid fish, but little tuna are rather commonly observed to jump repeatedly when they are feeding on surface forms. Kishinouye (1923) reported that *E. yaito* is a voracious species which "feeds on small fishes and medium-sized plankton." He further stated that it is a non-schooling form and when feeding on schools of small fishes it darts into the midst of the school and scatters them. When approached they generally sound or move out of the area. However, Mowbray (1956) noted that schools of little tuna which recorded on the echo sounder as swimming at a depth of 13 to 15 fathoms will invariably rise to the surface to take a trolled lure. Hiatt and Brock (1948) have described the herding of prey by *E. yaito* in the Pacific.

Both of us have noted the tendency for little tuna to regurgitate their food upon being hooked and landed, and this is well known to anglers. During the 12-month period of observations conducted at Pier 5, in only three cases was food taken from the stomachs of little tuna; one contained a shrimp, *Penaeus duorarum* Burkenroad, another had eaten a round herring, *Etrumeus sadina* (Mitchill), and the third contained an unidentified jack, *Caranx* sp. Postel (1956) noted that 97 of 100 stomachs of *E. alletteratus* from West Africa were empty. The remainder contained a squid pen, part of a clupeid and bits of wood.

The work carried on in 1951 by Rathjen was reported on in detail by Carlson (1952). In this study six different organisms were identified from little tuna stomachs. As noted in Carlson's paper, the round herring was the most important single item of food for this species and occurred about 39 per cent of the time in the stomachs which contained food. This species was followed in importance by several

unidentified species of squid (28 per cent). The Spanish sardine, *Sardinella anchovia* Valenciennes, also was of some importance and is utilized by some scombroids. Wallace and Wallace (1942) recorded *Etrumeus* as being one of the most important foods of the white marlin, *Tetrapturus albidus* Poey, in Maryland, the two species possibly competing for the same types of foods.

Longley and Hildebrand (1941) found halfbacks (Hemiramphidae) and needlefish (Belonidae) in specimens of *E. alletteratus* from the Florida Keys. The food of the little tuna caught on trolling gear in the southeastern United States has been reported by Anderson *et al.* (1956 *et seq.*). The diet found consisted primarily of fishes and squid, although a few crustaceans were listed. *Etrumeus sadina* appeared as a common item of food, and clupeids, engraulids, scombrids and carangids were also commonly observed. In Delaware and Maryland waters, little tuna were found to contain round herring, squid *(Lolliguncula brevis* and *Loligo peali),* sand lance *(Ammodytes),* and amphipods. Among a wide variety of organisms, in West Africa Postel (1950; 1954a) found a predominance of clupeids, scombrids, carangids, hemiramphids and exocoetids, as well as cephalopods, penaeid shrimp, copepods, decapods and mysids. Postel noted that little tuna did not feed when ripe.

Ronquillo (1954) recorded *Sardinella* from *Euthynnus pelamis* which is more of an offshore form, but does not list any organisms from the related *Euthynnus yaito* which were identical or similar to those which have been found in *E. alletteratus*. In his comprehensive study of the stomach contents of 75 specimens of *E. yaito,* Ronquillo recorded 33 categories of organisms. Of these, stomatopods and megalopa larvae were the most numerous organisms but it appeared that Myctophids, *Decapterus, Mene maculata,* and monacanthids occurred in the greatest bulk. Notable in his studies was the presence of numerous bathypelagic as well as offshore, pelagic species. Similar forms have not been observed in the food of *E. alletteratus*. This apparent difference in the food and feeding habits of such closely related species may indicate that either the two species were taken from widely different habitats which were due to selective fishing, or that the two species actively seek out different niches. Another interesting difference was the complete absence of cephalopods from the diet of *E. yaito;* in contrast, these are the second most abundant category for *alletteratus*. Williams (1956) has also reported that squids were relatively important as food of *E. affinis*. The great importance of

cephalopods as food for tunas *(Thunnus)* has been noted by de Sylva (1956), and it seems strange that such a staple food would not be taken by *E. yaito*.

Ommanney (1953) in a study of *E. affinis* from East Africa found a variety of organisms ranging from flying fish found at the surface to bottom-living gastropods, diodontids and eels. Unidentified smaller fishes, squids, blue mackerel *(Caesio)* and planktonic crustacea were most important in the diet in order of their frequency encountered in the stomach of this species.

The occasional habit of *Euthynnus* feeding on plankton was noted by Ommanney (1953) who found crab larvae and other macrocrustacea in *E. affinis* and by Williams (1956) who noted the presence of *Squilla* and other crustacean remains in this species. However, Williams noted that its main diet consisted of silversides *(Atherina* sp.), sardines (*Sardinella* sp.), squids and unidentifiable fishes. This diet seems more nearly like that of *alletteratus*. Williams concludes that "it is obvious that the bonito feeds at or near the surface, mainly on the small fishes, squids and plankton found there."

Apparently the little tuna is not a shoal-water fish around Bermuda, where there is little continental shelf, and Mowbray (1956) reports little tuna as common there, apparently occurring side by side with schools of blackfin tuna. In these deep waters he reported little tuna feeding on "a red squid and a small red shrimp." During the periods when they are feeding on these forms Mowbray noted that both the blackfin tuna and the little tuna will not take a lure that is not red, or partly red. The present study involved fish from rather shallow water, usually less than 20 fathoms, and since these red prawns are generally deepwater forms, their absence in the present study is not surprising.

That Mowbray (1956) observed fish on the echo sounder at 13 to 15 fathoms which shortly were taken by trolled surface lures indicates that this species, as in other tunas, has keen vision and is not loath to move to another area where food is more abundant. The tendency of other tunas to move rapidly back and forth between widely different strata has been noted for the oceanic bonito and the blackfin tuna by the authors. Frequently these species have been examined which had been recently caught on a surface-trolled lure during the daytime and have contained deepsea prawns, *Systellaspis debilis,* hatchet-fishes, *Argyropelecus* and *Polyipnus* spp., and lanternfishes, *Myctophum* spp., which were in excellent condition, indicating that they had been only recently ingested. Thus, our observations, and from a discussion of

findings of workers on other species, lead us to conclude merely that the little tuna occupies a wide variety of habitats, and as is the usual case with most species, it feeds on whatever food is the most available.

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EFFECTS OF HURRICANE DONNA ON THE TURTLE GRASS BEDS OF BISCAYNE BAY, FLORIDA[1]

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ABSTRACT

The dry and wet weight of *Thalassia testudinum* König washed ashore at Biscayne Bay during Hurricane Donna of 1960 is estimated. Agents destructive to turtle grass, other than wind, are discussed, and additional observations are included of hurricane damage to the turtle grass beds of the Bahama banks.

INTRODUCTION

The shallow water marine monocotyledon, *Thalassia testudinum* König, occurs from about Indian River, Florida, to Brazil, including the north coast of Central America, the Caribbean Islands, and the Gulf of Mexico (Voss and Voss, 1955; Rodriguez, 1959; Voss, personal communication, 1961). Known as turtle grass throughout its range, in Florida it occurs in dense beds from Biscayne Bay through the Keys and along the west coast. It covers much of the bottom of Biscayne Bay and many animals and plants are associated with it. Voss and Voss (1955) have commented upon its importance as an organic producer, and Odum (1957) and Odum, Burkenholder and Rivero (1960) have indicated a high productivity rate. Pomeroy (1960) found little difference in productivity between bottoms bare of *Thalassia* and those covered with *Thalassia* but concludes that the *Thalassia* may be shading the microflora beneath it, in which case productivity figures for the *Thalassia* would be exclusive of benthic microflora. Current studies at The Marine Laboratory, University of Miami (unpublished) indicate a very rapid growth rate.

As *Thalassia* grows it continually fragments. Besides fragmentation due to dying of the tips and subsequent breakdown of the cell walls, Phillips (1960) notes a great amount of leaf kill and fragmentation associated with extremes of temperature. Healthy green blades are also broken off by larger invertebrates moving about over the grass beds. Such heavy gastropods as *Strombus gigas* and *Pleuroploca gigantea* probably break some blades free from the rhizome merely by crawling over them. In shallow coastal waters mullet, *Mugil* spp.,

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feed among the roots of *Thalassia* in large schools, tearing loose vast amounts of the leaves and muddying the entire feeding areas. The echinoids *Tripneustes esculentus* and *Lytechinus variegatus* actively feed upon *Thalassia* and possibly break many blades free during their feeding activities. *Thalassia* blades are often scalloped along their edges, the scalloping sometimes extending halfway through the blade as if it had been browsed upon by some animal. It is likely that other organic agencies, including pathogens, contribute to the fragmentation of the blades. Finally, aside from some breakage due to boating, swimmers, etc., wind storms and accompanying turbulent water break many weakened and possibly even healthy blades. Occasionally whole rhizomes are washed free of the substrate.

When old, dying blades are broken from the rhizome, or when deteriorating tips are broken from the green portion of the blade, they tend to sink and be trapped between healthy blades. Accumulations of dead and decaying blades several inches thick may lie among the upright green blades of some *Thalassia* beds, particularly in areas of little current. Further evidence of blade deposition may be seen in the sand "pot-holes," varying in diameter from a few to many feet, which are often scattered through *Thalassia* beds. The bottoms of such pot-holes are frequently covered by dead blades, sometimes to a depth of over 12 inches, depending upon the amount of current present and the pot-hole contour.

When green "healthy" blades break free they usually float. These floating green blades wash up onto the shore of Biscayne Bay throughout the entire year, and windrows of blades may often be seen floating about in the bay. Indeed, their presence often forms a hindrance to outboard motorboat navigation, fouling the propellers or rudders. With an onshore wind the blades are driven shoreward and deposited in long piles or windrows. These piles of debris contain, besides *Thalassia,* blades of two less common monocotyledons, *Diplanthera wrightii* (Ascherson) and *Syringodium filoforme* Kützing, several species of marine algae, pieces of terrestrial spermatophytes, dead fish, and the usual human artifacts. During Hurricane Donna (September 9 and 10, 1960) Biscayne Bay was buffeted by high winds which caused a great deal of *Thalassia* to break free and accumulate on the shore. Some rhizomes were washed out of the substrate in the portion of the bay investigated but the windrows were composed mainly of *Thalassia* blades. The writers, who have recently

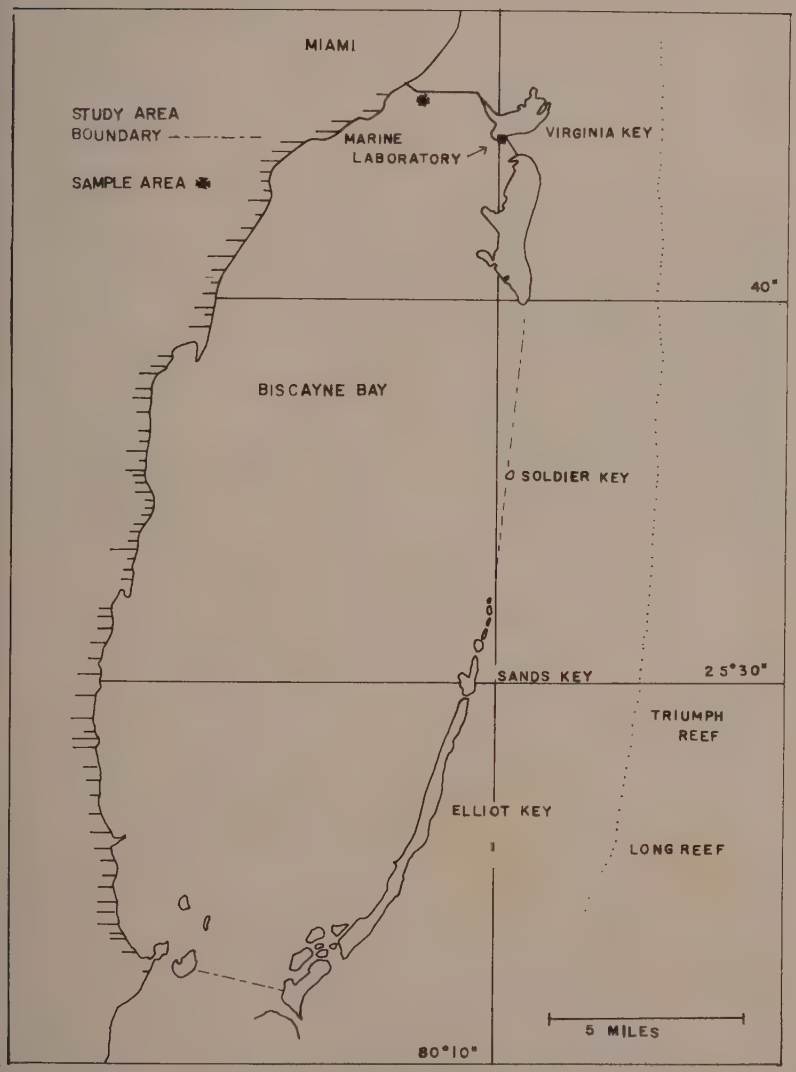

FIGURE 1. A map of the study area showing localities mentioned.

begun a study of the *Thalassia* community under National Science Foundation grant G-14521, seized upon the opportunity to try to determine the amount of *Thalassia,* by weight, washed ashore in Biscayne Bay by Hurricane Donna, and the damage to the *Thalassia* beds relative to this amount.

Methods

On September 12, 1960, a large part of the shore of Biscayne Bay from Rickenbacker Causeway south to Matheson's Hammock wading beach was inspected. It appeared that areas directly exposed to the Bay (*i.e.,* not sheltered by islands) had all received roughly the same amount of *Thalassia.* This is understandable when it is considered that the wind shifted considerably during and after the storm. (U.S. Weather Bureau, Surface Weather observations for Sept. 9, 10, and 11, 1960). The writers chose an area along Rickenbacker Causeway at the north end of the Bay (Figure 1) as having a *Thalassia* windrow typical in size and shape of those observed elsewhere. A sample 1 meter wide and 10 meters long (Figure 2) was removed from the windrow. After being washed and cleaned of extraneous material, the sample was spread on a chicken-wire platform to dry. The platform was so constructed that it could be moved in and out of a rain shelter, and the sample was sun and air dried for 22 days (from September 13 to October 4, 1960). When the dry weight appeared to have stabilized, the sample was weighed. The weight thus obtained was taken to represent the dry weight of *Thalassia* found in one meter of the windrow lining the shore of the study area. A planimeter was used to calculate the area of the bay under consideration, and the length of shore bearing a *Thalassia* windrow was "stepped off" with calipers. The Miami Weather Bureau provided Surface Weather Observations for September 9th and 10th and a mimeographed hurricane report which was issued September 27th. Visual observations of Biscayne Bay *Thalassia* beds have been made on an average of twice a week since September 29th by the authors. Before Hurricane Donna the *Thalassia* beds of Biscayne Bay had been collected and observed by members of The Marine Laboratory staff for more than 15 years. Since wet weight of the original windrow sample of *Thalassia* was not taken, a 500 gram wet sample of fresh green *Thalassia,* including *aufwuchs,* was obtained from the beach in front of the Laboratory and sun dried in order to obtain a wet weight to sun-dried weight relationship.

FIGURE 2. A windrow of *Thalassia* showing the sample partially removed. Note the meter-stick in the foreground.

RESULTS

The sample of *Thalassia* representing that deposited in a windrow along one meter of shore line weighed (after sun drying) 37 lbs. (slightly more than 16.78 kg). The portion of the bayshore investigated (fig. 1) was calculated to be 84,786 meters long; thus the total weight of *Thalassia* windrow present in the study area is assumed to be 3,137,082 lbs., or 1,422,971 kg (sun-dried weight). Because our sample had started to dry before it was collected, no effort was made to obtain a wet weight. However, a 500 g. sample of wet *Thalassia* was dried to yield to 100 g. dry weight. The wet sample was allowed to drain for about 10 minutes before weighing. The five to one ratio thus obtained allows the authors to estimate a wet weight of 15,685,-410 lbs. or 7,114,855 kg. of *Thalassia* windrow for the 84,786 meter shoreline investigated. This is a low estimate when one considers that a great deal of *Thalassia* was carried hundreds of feet inland by wind and water and that the windrow observed was probably deposited by several high tides in the 48 hrs. following the storm. It would

hardly be an exaggeration to say that the dry and wet weight figures could total half again as much if all the widely scattered *Thalassia* were taken into account.

Despite the seemingly large weight of the *Thalassia* blades deposited upon the shore there appears to have been little damage to the *Thalassia* beds contained within the 492.19 sq. km. (190 sq. mi.) of the study area. The authors have traveled over a large portion of the bay since the storm and have seen no severe damage to the beds. At worst there has been a thinning of shallow water growth with a concurrent displacement of associated invertebrates, particularly echinoids. Damage to the *Thalassia* and associated fauna and flora due to fresh water run-off in near-shore areas could be more severe than physical storm damage. Growth studies now in progress at The Marine Laboratory indicate that a 25 mm growth increment per week is not remarkable for individual *Thalassia* blades. Thus it would appear that physical damage may be quickly repaired.

An interesting observation regarding storm effects on *Thalassia* was made by Harvey R. Bullis, Jr. of the U.S. Fish and Wildlife Service. Following Hurricane Donna, he noted (personal communication) that the bottom along the west side of the Bahama Banks, from a depth of 100-150 fathoms to 250-300 fathoms, was blanked by decaying vegetation which included a high percentage of *Thalassia* rhizomes and blade fragments. Along with the *Thalassia* were rhizomes and blades of *Diplanthura, Syringodium* and some *Sargassum* fragments. Bullis found a great reduction in numbers of bottom fish in areas covered by the decaying vegetation.

Conclusions

Tropical Hurricane Donna of 1960 subjected Biscayne Bay to winds with maximum gusts of approximately 80 miles per hour in the northernmost portion of the study area and approaching or exceeding 100 miles per hour in the southernmost portion. The eye of the storm passed over the center of the Florida Keys between 2 and 3 a.m. September 10th, and its effects were felt in the Miami area for more than 24 hours before and after the passage of the eye over the Keys. In the Biscayne Bay area there was considerable waterfront damage. Unprotected boats were driven ashore or broken up and the shore line was altered in many places. Although a great deal of *Thalassia* was

washed ashore, damage to the *Thalassia* beds is considered light, and a rapid growth rate may contribute to early recovery from storm damage.

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RAPID VOLUMETRIC DETERMINATIONS OF SULPHATE, CALCIUM, AND MAGNESIUM IN HIGH LIME-MAGNESIAN BRACKISH COASTAL WATERS[1]

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ABSTRACT

Rapid methods for determining the sulphate, calcium, and magnesium content of brackish coastal waters are desired by geologists and biologists working in Mississippi Sound. They need daily, even hourly, analyses to correlate with other records. Investigators on other coasts have the same need. Gravimetric and colorimetric methods are too slow and ponderous and are too difficult to use on shipboard. However, new titrants and new indicators permit titrating brackish water for sulphate, calcium, and magnesium ions in 5 to 10 minutes, each. Procedures are modifications of recognized methods. The disodium dihydrogen dihydrate of Ethylenediaminetetraacetic acid (EDIA) is used as a titrant to complex barium, calcium, and magnesium ions. Only three samples of brackish water are necessary: one to determine combined calcium, magnesium, and excess barium; one to determine the amount of combined calcium and magnesium; and one to find the amount of calcium alone. Simple calculations show the amounts of sulphate, calcium, and magnesium ions.

INTRODUCTION

Cation and anion content of Mississippi Sound waters vary so much laterally, vertically, and hourly that geologists and biologists have difficulty in correlating their findings with water behavior. Greater variations are reported on other low indented coasts. The need has been for speedy analyses on a daily, even hourly, basis which can be used by geologists and biologists who have had little training in quantitative analysis. Investigators on other coasts have the same need.

Three of the important variables, which can be determined by rapid volumetric methods, are sulphate, calcium, and magnesium. They are the subject of this report. In 1959 Price and Priddy published a simple, rapid colorimetric method of determining nitrite and nitrate content of brackish Mississippi Sound waters. It is hoped to report soon on other rapid procedures for analyzing phosphate, sulphite, sulphide, and dissolved hydrogen sulphide. It is also hoped to work

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out short, volumetric schemes for finding the content of aluminum, ferric iron, potassium, barium, and strontium.

Fortunately, recent volumetric methods have been developed which enable the analysis of many ions which are found in varying concentrations in Mississippi's coastal waters. There is a host of new indicators, and, best of all, there are derivatives of Ethylenediaminetetraacetic acid (EDTA) which are used as complexing agents permitting analysis of one cation in the presence of several cations and many anions. Thus calcium and magnesium ions can be measured readily. By determining the used concentrations of introduced cations the amounts of certain anions in brackish water, such as sulphate, can be measured.

To perfect rapid titrations of calcium and magnesium using EDTA the procedures of de Sousa (1953), de Sousa (1954), Hildebrand and Reilley (1957), Lott and Cheng (1957), and Welcher (1958) were reviewed.

When it was realized that the high calcium and magnesium content of brackish coastal waters enhanced the complexing action of EDTA with barium a convenient method of determining sulphate became available. Volumes of standard barium chloride known to be in excess of that needed to precipitate all the sulphate as insoluble barium sulphate were used and the excess titrated with EDTA. The sulphate procedure was perfected after reviewing the work of Welcher (1958) and Reilley, Schmid, and Sadek (1959), the key factors being pH control and appropriate indicators. As Reilley (1959) has pointed out, methyl thymol blue is an excellent indicator for barium (SO_4) determination in alkaline media but it is not suitable when calcium and magnesium are present. Several indicators, Eriochrome Black T, Calcon, Calcein, Calgamite, Eriochrome Blue S. E., and Zinchrome R, and various combinations of the above, were tested in Millsaps College laboratories to determine which gave the sharpest end point at the proper pH.

The advantage of performing the barium (SO_4), calcium, and magnesium titrations in sequence is that two indicators, used singly or mixed in equal proportions, will suffice. Experience shows that mixed Eriochrome Blue S. E.[4] and Calgamite[5] give the sharpest end point in

[4] 3-(5-chloro-2-hydroxyphenylazo)-4, 5 dihydroxy 2, 7 Naphthalenedisulfonic Acid Disodium Salt, obtainable from Distillation Products Industries, Cat. #7571. Also obtainable from National Aniline Division of Allied Chemical Co.

[5] 1-(1-Hydroxy-4-methyl-2-phenylazo)-2-Napthol-4-Sulfonic Acid, obtainable from G. Frederick Smith Chemical Co., Columbus, Ohio.

the titration of calcium and magnesium, as well as the titration of calcium, magnesium, and barium. On the other hand, the best results are obtained by using Eriochrome Blue S. E., alone, in the titration for calcium at pH 13. Unfortunately this, as well as all other calcium indicators, does complex the very small concentrations of strontium and the results are in error by the amount of this metal in solution. The calcium to strontium ratio is known to be very large in sea water; consequently the error in this determination, due to presence of strontium, is very small. As the calcium to strontium ratio is thought to be fairly constant it might be determined one time for a given region, and thereafter a correction applied to all EDTA titrations.

This paper includes directions for making all reagents. Step by step instructions are given which may seem superfluous to analytical chemists but which are essential to biologists and geologists. Comments are made on the chemistry involved in each step. Finally the calculations are set up as simple problems.

Strength of titrant and volumes of brackish water samples taken for analysis are selected in such a way as to insure maximum accuracy in volumetric procedures. Investigations over a period of three years have shown that EDTA solutions of more than one molarity are required in order to use 20 to 40 ml of EDTA in each titration, in accord with the best volumetric procedures.

The volumes of EDTA used reflect tidal movements and amount of rainfall. During low tides or periods of excessive runoff from the Mississippi mainland 0.015 molar EDTA is used to titrate 100 ml brackish water for combined calcium and magnesium, or to titrate 50 ml of brackish water for calcium alone. In contrast, during high tides and periods of minimum rainfall 20 to 40 ml of 0.03 molar EDTA per titration are required, using the comparable volumes of brackish water. For samples taken near the barrier islands at the south margin of Mississippi Sound even stronger solutions of EDTA are necessary to maintain the same degree of accuracy. Although there has been no opportunity to check, it is likely that yet stronger EDTA solutions will be required along Florida's Gulf Coast where runoff is from a limestone and dolomitic terrain.

Because EDTA complexes with divalent, trivalent, and tetravalent cations in only a 1 to 1 molecular ratio, any given molarity of titrant will react volume for volume with the same molarity of cations. Reagent grade of EDTA of Primary Standard purity is now supplied by

most chemical houses. By accurately weighing the appropriate quantities of this reagent, Disodium Ethylene Diamine Tetraacetate Dihydrate, which fortunately has the high molecular weight of 372.3, it is possible to prepare solutions which require no standardization. These solutions remain stable for periods of five months or longer when stored in polyethylene or hard glass bottles. However, if stored in soft glass bottles, the titer should be checked at intervals of three weeks against standard solutions of calcium or magnesium.

Directions for Preparing Solutions

1. 0.025 molar EDTA — (the titrant).
   Weigh exactly 18.615 grams of reagent grade Disodium Ethylene Diamine Tetraacetate Dihydrate into a 2 liter volumetric flask. Add about 500 ml of freshly distilled water and shake the flask vigorously to bring about complete solution. Dilute to the mark and mix well. Each milliliter of this solution is equivalent to 1 mg calcium, 0.6 mg magnesium, and 2.4 mg sulphate ion.

2. 0.025 molar calcium chloride — (for checking titer of EDTA).
   Dry a sample of reagent grade calcium carbonate in an oven at 110° C for two hours. After the sample has cooled in a desiccator weigh exactly 2.5 grams of it into a 400 ml beaker. Carefully dissolve the carbonate in about 25 ml of dilute hydrochloric acid (1 volume acid to 2 volumes water). Place a watch glass over the beaker and heat the contents to boiling in order to drive off carbon dioxide. Cool to room temperature and then transfer the contents to a 1 liter volumetric flask. Dilute to the mark and mix well. Each ml of this solution contains 1 mg calcium.

3. Buffer mixture — (to maintain a pH of approximately 10 in the titration of calcium and magnesium, and for calcium and magnesium combined with excess barium chloride in the sulphate determination).
   On a rough balance weigh 67.5 grams of reagent grade ammonium chloride. Dissolve in 200 ml of distilled water and then add 570 ml of reagent grade ammonium hydroxide. Dilute this solution to one liter and mix well.

4. Basic solutions — (to attain a pH of approximately 13 in calcium titration).

A. Reagent grade diethylamine may be used at full strength.

B. One molar sodium hydroxide can be used instead of the diethylamine, but the end point obtained with the indicator in this medium is not quite as sharp. To prepare this solution dissolve 40 grams of the reagent grade sodium hydroxide in freshly distilled water and dilute to one liter. This solution should be stored in a polyethylene bottle.

5. Reagent grade ammonium hydroxide — (to neutralize the hydrochloric acid used in the precipitation of $BaSO_4$).
Use at full strength.

6. 0.025 molar barium chloride solution — (to precipitate the sulphate).
Weigh 12.215 grams of fresh $BaCl_2 \cdot 2H_2O$ (molecular weight 244.3) and transfer to a 2 liter flask. Dissolve in about 500 ml distilled water, dilute to mark, and mix well. If the weighing is carefully done and the $BaCl_2 \cdot 2H_2O$ has not dried out it may be assumed that this solution will react ml for ml with the 0.025 molar EDTA—and that the sulphate titer is 2.4 mg per ml. However, if the reagent is old it is always good quantitative procedure to check all solutions. To determine the titer of this barium chloride-pipette 25 ml into a wide mouth 500 ml flask, add about 50 mg of the dry methylthymol blue indicator and concentrated ammonium hydroxide a drop at a time until a very intense blue color results. Then pass in EDTA from the burette to get a sharp change to light grey. The barium chloride/EDTA volume ratio will be 25/ml EDTA used in titration. Alternately, this volume ratio may be obtained by adding a known volume of the standard calcium solution to 25 ml of the barium chloride and titrating with the EDTA using Eriochrome Blue S.E. as the indicator.

7. Indicators

A. For fixing correct pH values.

(1) Thymolphthalein — (used in sulphate determination to fix pH at 10).
Dissolve 0.1 gram reagent in 100 ml ethyl-alcohol.

(2) Rosanilin hydrochloride — (used in calcium determination to fix pH at 13).

Dissolve 0.1 gram reagent in 100 ml distilled water.

B. Complexometric, for titration with EDTA.

(1) 0.1 gram Eriochrome Blue S.E. — (for calcium titration).
Grind finely with 10 grams reagent grade potassium chloride. Store in a small dark glass bottle. This mixture is quite stable. The quantity is enough for many titrations because only about 50 mg are required at one time.

(2) Mixed indicator — (for the sulphate and combined calcium and magnesium determinations).
Grind finely with 0.1 g Eriochrome Blue S.E. and 0.1 g Calgamite with 20 grams reagent grade potassium chloride.

(3) Methylthymol Blue — (for comparing EDTA and barium chloride solutions).
Grind 0.1 gram solid with 10 grams reagent grade potassium chloride. This indicator is obtainable from Dojinde & Company, Ltd., 38 Kamitoricho Kumamoto-Shi, Japan.

Note: These complexometric indicators are stable for months when prepared dry, as above. Their solutions are more convenient to use but they are stable for only two or three weeks. Solutions can be made as follows: for Eriochrome Blue S.E. dissolve 0.1 g in 100 ml water; for mixed indicator dissolve 0.1 g each of Calgamite and Blue S.E. in 100 ml water; for methylthymol Blue dissolve 0.1 g of reagent in 100 ml of ethyl-alcohol.

Procedure

1. For sulphate determination:
Pipette a 25 ml sample of brackish water into a 500 ml wide mouth flask, add 5 ml concentrated HCl and heat to boiling. Next add, with a pipette, 25 ml of 0.025 molar $BaCl_2$ solution and allow to digest over low flame until the precipitate of $BaSO_4$ settles. Remove from the heat and cool to room temperature by

immersion of the flask in cold water. Now add a few drops of Thymolphthalein indicator and concentrated ammonia, drop by drop, until a faint blue color just appears. Finally add 5 ml of ammonia-ammonium chloride buffer and titrate with EDTA in the presence of approximately 50 mg Calgamite-Eriochrome Blue S.E. mixture, to a purplish-blue end point.

2. For combined calcium and magnesium determination:
   Pipette 25 ml brackish water into the 500 ml flask, add 5 ml ammonia-ammonium hydroxide buffer, and 50 mg mixed Eriochrome Blue S.E. and Calgamite. Titrate to a blue end point.

3. For calcium determination:
   Pipette a 100 ml sample of brackish water into a 500 ml wide mouth flask. Add two drops of Rosanilin hydrochloride indicator and then add Diethylamine carefully until the red color of the indicator just becomes colorless. (One molar sodium hydroxide solution may be substituted for the diethylamine.) If this operation is carefully executed the pH is approximately 13, and the magnesium is present chiefly as the undissociated magnesium hydroxide $Mg(OH)_2$. If a pH meter is available the use of the Rosanilin may be avoided. In either case, one or two trials will serve to establish the approximate volume of basic material needed for all subsequent titrations and this part of the operation need not be repeated with every titration. Now add about 50 mg of the dry Eriochrome Blue S.E. salt mixture and titrate to a purplish-blue end point.

Calculations

1. An example of a sulphate determination:
   25 ml (which is 1/40 of a liter) of the brackish water plus 25 ml of the barium chloride solution treated according to step (1) of the procedure used 44.3 ml of the 0.025 molar EDTA (complexed were calcium, magnesium, and the excess barium not needed for the precipitation of barium sulphate). 25 ml of the water treated according to step (2) of the procedure used only 34.8 ml of the 0.025 molar EDTA (complexed were calcium and magnesium).
   Then $44.3 - 34.8 = 9.5$ ml of the EDTA is equivalent to the excess barium chloride in solution. In this case the $BaCl_2$/EDTA

volume ratio = 1. Therefore, 25 - - 9.5 = 15.5 ml of the $BaCl_2$ actually used in reacting with the sulphate content of 25 ml brackish water. 15.5 x 2.4 (the SO_4 titer of the EDTA) = 37.2 mg sulphate.

Parts per million (or mg per liter) SO_4 = 37.2 x 40 = 1488.

By comparison, using the conventional gravimetric method, 1470 parts per million was obtained. Geologists and biologists believe that this amount of difference is of little consequence. They are willing to trade 20 or 30 sulphate determinations per day of this accuracy for one or two reliable gravimetric determinations per day.

2. An example of calcium determination:

100 ml (1/10 of a liter) of brackish water when treated according to step (3) of the procedure used 23.8 ml 0.025 molar EDTA (complexed was calcium only) 23.8 x 1 (the calcium titer of the EDTA) = 23.8 mg calcium per 100 ml of the water.

Parts per million (or mg per liter) calcium = 10 x 23.8 = 238.

3. An example of magnesium determination:

25 ml of brackish water treated according to step (2) of the procedure used 34.8 ml of the EDTA. 100 ml would use 4 x 34.8 = 139.2 ml to complex calcium and magnesium. 100 ml of the water treated according to step (3) used 23.8 ml to complex calcium alone. 139.2 - - 23.8 = 115.4 ml EDTA used to complex magnesium, alone, in 100 ml (1/10 of a liter) brackish water 115.4 x 0.6 (magnesium titer of EDTA) = 69.2 mg magnesium in 100 ml water.

Parts per million (or mg per liter) magnesium = 69.2 x 10 = 692.

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GASES IN BOTTOM SEDIMENTS

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ABSTRACT

An activated carbon chromatographic column was used in Fisher-Gulf Gas Partitioner to analyze one ml gas samples from shallow water sediments. Small bubbles rising from undisturbed hard bottoms were pure O_2, large bubbles pure CO_2. Methane and H_2S were found only in mud-muck bottoms with copious evolution of gas.

Although it is common knowledge that gases do occur in bottom sediments, very little information on this subject can be found in the literature. Perhaps one reason for this is the difficulty of analyzing the small gas samples which are usually obtained. The availability in our laboratory of a Fisher-Gulf Gas Partitioner gave us an opportunity to make some studies of a preliminary nature on the composition of gases found in our local sediments.

The chromatographic column supplied by the manufacturer as a standard item uses tri-m-cresyl phosphate as the liquid coating on inert granules. We found this to be unsatisfactory, particularly when H_2S was present. A column 7 ft long, of 0.25 inch OD copper tubing packed with a mixture of 32 to 60 mesh activated charcoal proved to have suitable characteristics, when helium was used as a carrier gas. It was tested with pure N_2, O_2, CO_2, CH_4, H_2S and H_2O vapor and various mixtures of these gases as well as air. Water vapor and H_2S were not retained in the column. The inability to detect water vapor was no real loss and no effect from H_2S was preferred to the troublesome effect of H_2S in the tri-m-cresyl phosphate column.

The retention times of N_2, O_2 and air were so close that it was not possible to separate them, at least with the flow rates, temperatures and sensitivity settings appropriate to the detection of CO_2 and CH_4. Optimum settings for a 1 ml sample were: temperature, 140°C; flow rate, 40 ml minute; sensitivity, 20. Under these conditions, the retention time of N_2, O_2 or air was 1 minute, CH_4 was 2 minutes and CO_2 was 6.5 to 9 minutes. Although the retention time of CO_2 was not consistent, the shape of the curve was distinctive enough so that the peak could be identified with little difficulty.

Field Tests: Gas samples were taken at several locations in shallow-water zones of St. Andrew Bay. Sand bottom, grass (mixed *Thalassia* and *Diplanthera*) bottom and mud flats were sampled by water dis-

placement in a 4 oz. glass jar placed over an inverted funnel of about 18 inch diameter and 20 inch height. In some tests, the funnel was left undisturbed for 10 to 30 minutes; in others, the bottom under the funnel was raked and otherwise thoroughly disturbed to release gases trapped in the sediment. A third procedure was to collect bubbles individually as they were seen to rise from the bottom. These varied from about 1 to 4 mm in diameter. In a few instances, large quantities of bubbles were seen to rise after the bottom had been disturbed by walking on it. These, too, were collected individually until a sufficiently large sample (2 to 5 ml) was obtained.

Typical results of these field tests are given in Table 1. Where O_2 is listed, its presence is inferred since O_2 is expected to be liberated by photosynthesis. A 1 ml sample was used in the gas analyzer.

TABLE 1

Typical Analyses of Gases in Shallow-Water Sediments of St. Andrew Bay, Bay County, Florida

Bottom Type and Method of Collection	Quantity of Gases Collected	Per Cent Composition by Weight
Grass bottom, undisturbed for 30 min., funnel	10 ml	100% O_2
Disturbed mud bottom, funnel	75 ml	4% O_2, 96% CO_2
Disturbed grass bottom, funnel	23 ml	13.2% O_2, 86.8% CO_2
Disturbed sand bottom, funnel	52 ml	20.6% O_2, 79.6% CO_2
Bog bottom, Lake Poltergeist,* copious evolution, no funnel required	Unlimited	0.4% O_2, 1% CH_4, 98.6% CO_2 plus obvious but indeterminate amount of H_2S
Soft mud bottom with free evolution of gas bubbles collected individually	—	5.5% O_2, 4.4% CH_4, 90.1% CO_2
Large bubbles individually collected from slightly disturbed grass bottom	—	100% CO_2

*A dystrophic salt-water lagoon at 30°9′44″N and 85°44′30″W.

The field observations and analyses permit some fairly definite conclusions which, while neither profound nor particularly novel, are consistent with what one might expect. Bubbles arising from grass flats were nearly always small. When collected with the funnel, analysis showed the gas to contain no CH_4 or CO_2. This leads to the inference that it is pure O_2. When the bottom was disturbed, large bubbles were always seen to rise. When collected individually, the

composition was 100% CO_2. When collected with the funnel, up to 20% oxygen was found, but the only other gas was CO_2. It is apparent then, that the major constituent, if not the only one, of gases *within* the sediment is CO_2 and this accumulates as large bubbles. Methane was found only in soft mud or muck bottoms exhibiting free evolution of gas.

LARVAL AND ADULT STAGES OF THE STROMATEOID FISH *PSENES REGULUS* WITH COMMENTS ON ITS CLASSIFICATION[1]

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ABSTRACT

A series of 21 specimens of *Psenes regulus* Poey from the Western North Atlantic is described and seven specimens are figured, including specimens larger and smaller than previous descriptions. Graphs of body proportions are presented to show developmental changes. Changes in body depth are strikingly different from the genotype, *Psenes cyanophrys*. Other differences are the relatively low soft-ray counts of dorsal and anal fins, a slender caudal peduncle bearing keels and a stiff, widely forked caudal fin. These suggest a closer relationship to the genus *Ariomma* than to *Psenes* in the admittedly unsatisfactory classification of the stromateoid fishes. *Psenes regulus, Cubiceps dollfusi, Cubiceps nigriargenteus, Cubiceps melanus* and *Paracubiceps ledanoisi* are allocated to the genus *Ariomma*. The reasons for this are discussed.

Available data indicate that *P. regulus* is a tropical, marine fish which is occasionally found in more northerly areas of the Gulf Stream.

Postlarval and prejuvenile specimens are generally taken over deeper waters than those where juveniles and adults are taken.

INTRODUCTION

During the past few years the Marine Laboratory collections have acquired a series of postlarval and juvenile specimens of *Psenes regulus* Poey, 1868. The postlarval development of this species, undescribed until now, differs strikingly from the development of *Psenes cyanophrys* Valenciennes, 1833, as described by Legaspi (1956). Specimens of the U. S. Fish and Wildlife Service and University of Michigan collections show that *P. regulus* attains a larger size than formerly believed, and in these larger stages exhibits characters not present in the smaller, described specimens. Due to these factors, the author believes that *Psenes regulus* should be removed from the genus *Psenes* Valenciennes, 1833 and placed in the genus *Ariomma* Jordan and Snyder, 1904 in the current, and admittedly unsatisfactory, classification of stromateoid fishes.

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Many workers have aided the author and he wishes to express his thanks to them. Dr. James E. Böhlke. Academy of Natural Sciences of

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Philadelphia, and Dr. Norman B. Marshall, British Museum, examined material for the author. Dr. Reeve M. Bailey, Museum of Zoology, University of Michigan, Dr. Giles W. Mead, Museum of Comparative Zoology, and Dr. Leonard P. Schultz, U. S. National Museum, lent specimens. Frederick H. Berry and Harvey R. Bullis, Jr., U. S. Fish and Wildlife Service, Dr. Carl L. Hubbs, Scripps Institution of Oceanography, Dr. Ernest P. Lachner, U. S. National Museum, Dr. Edward M. Nelson, School of Medicine, University of Puerto Rico, and Dr. Vladimir Walters, American Museum of Natural History, aided in a variety of ways. Walter R. Courtenay, Jr., Howard R. Foulk, Kenneth Hines, Andrew E. Jones, and Walter A. Starck, II, all of the Marine Laboratory, helped in various ways.

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Material and Methods

Collection data concerning the specimens utilized in this study are presented in Table 1. The vessels ALBATROSS, COMBAT and SILVER BAY are, or were, U. S. Fish and Wildlife vessels. The vessels DANNY BOY and MARK THOMAS are Key West shrimp trawlers, and GERDA is a Marine Laboratory research vessel. All depths are given in meters.

Most specimens are somewhat damaged. Scales have been entirely or partially lost from most specimens and fin rays are usually broken. The smaller specimens have faded in preservative, but most were examined while still fairly fresh.

Measurements.—Measurements were taken as suggested by Hubbs and Lagler (1958 edition). Small specimens were measured with an optical micrometer and larger ones with dividers. Measurements are given in Table 2. All are in millimeters and were taken from the left side of the specimen unless that side was badly damaged. Specimens are frequently referred to by their length or size. When this is the case, the reference is to standard length unless otherwise stated.

Pelvic-fin angle is the angle between a line running vertically through the center of the pupil and a line from the center of the pupil to the anterior edge of the pelvic-fin spine where this spine joins the body. This measurement was taken with a protractor with a length of thread attached to its focus. The specimen was positioned with the center of its pupil at the protractor focus and the middle of its caudal

TABLE 1

DATA FOR SPECIMENS OF *Psenes regulus* EXAMINED.

Catalogue No. or Station	St. L. (mm) of specimens	Vessel	Gear	Date	Location	Tow Depth (meters)	Bottom Depth (meters)
Supl. 188	5.3, 14.1	GERDA	2 meter dia. plankton net	6 May 1958	10 mi. E. Miami, Fla.	*ca.* 335	*ca.* 631
Supl. 177 & 179	7.0, 10.2, 16.4	GERDA	2 meter dia. plankton net	30 Jan. 1958	1 mi. E. Miami, Fla.	*ca.* 100	*ca.* 396
Supl. 183	15.0, 17.0	GERDA	2 meter dia. plankton net	1 April 1958	25°42′N, 79°46′W	*ca.* 425	*ca.* 750
USNM 174979	15.1, 15.3, 25.8	—	—	19 May 1955	off Big Wood Cay, Andros I.	*ca.* 31(?)	*ca.* 1530(?)
—	8.5	GERDA	midwater trawl	13 April 1959	10 mi. E. Miami, Fla.	*ca.* 100	*ca.* 631
—	14.8	GERDA	midwater trawl	21 May 1959	11°57.5′N, 65°03′W to 11°43′N, 65°07.5′W	*ca.* 330	*ca.* 900
UMML 2460	39.7	COMBAT	40 ft. flat trawl	3 Oct. 1957	31°32′N, 79°44′W	*ca.* 64.1	*ca.* 64
USNM 39329	46.0	ALBATROSS	beam trawl	21 Oct. 1885	32°24′N, 76°55.5′W	*ca.* 966	*ca.* 966
USNM 131629	57.4	ALBATROSS	beam trawl	21 Oct. 1885	32°27.5′N, 77°20.5′W	*ca.* 646	*ca.* 646
—	91.2	DANNY BOY	shrimp trawl	23 Feb. 1959	Rebecca Channel, Tortugas Ground	*ca.* 26	*ca.* 26
UMML 835	120.5	MARK THOMAS	shrimp trawl	28 Dec. 1956	25 mi. SW black can buoy off Sanibel I., Fla.	*ca.* 18	*ca.* 18
UMMZ 174105	147.5	SILVER BAY	New England fish trawl	11 May 1958	22°34′N, 89°56′W to 22°25′N, 89°47′W	*ca.* 77(?)	*ca.* 77(?)
—	149.8	SILVER BAY	New England fish trawl	9 May 1958	21°44′N, 91°07′W	*ca.* 43	*ca.* 43
—	183.2	SILVER BAY	V-D fish trawl	7 Sept. 1958	26°20′N, 85°50′W 25°10′N, 82°13′W to	*ca.* 37	*ca.* 37
—	117.0	DANNY BOY	shrimp trawl	15-17 Jan. 1960	24°49′N, 82°12′W	*ca.* 24-26	*ca.* 24-26

TABLE 2

MEASUREMENTS AND COUNTS OF 21 SPECIMENS OF *Psenes regulus*.

Measurements in Millimeters								Counts			
Standard Length	Head Length	Snout Length	Orbit Diameter	Predorsal Length	Least Depth of Ped. Caudal	Greatest Body Depth	Pelvic Angle	Dorsal Fin	Anal Fin	Pectoral Fin R L	Gill Rakers
5.3	2.3	0.7	1.0	2.8	0.6	—	17°	XII, 15	III, 15	—	?-1-10
7.0	3.1	0.8	1.3	3.4	0.8	3.4	29°	XII, 15	III, 15	— 18+	—
8.5	3.7	1.0	1.6	4.3	0.9	4.2	30°	XII, 15	III, 15	21-20?	6-1-16
10.2	4.3	1.0	1.9	5.0	1.0	4.6	34°	XII, 15	III, 15	21-21	5-1-16
14.1	5.9	—	—	—	1.2	—	41°	XII, 15	III, 15	22-21	7-1-16
14.8	6.0	1.4	2.4	6.3	1.1	6.0	36°	XII, 15	III, 15	— 21?	8-1-15
15.0	6.3	1.4	2.4	7.0	1.3	6.6	43°	XI-I, 15	III, 15	22-22	—
15.1	6.1	1.5	2.5	7.2	1.2	6.5	40°	XI-I, 15	III, 15	21-22	7-1-14
15.3	6.3	1.5	2.7	6.9	1.2	6.3	42°	XI-I, 15	III, 15	21-22	—
16.4	6.7	1.7	2.5	7.2	1.3	6.7	41°	XI-I, 15	III, 15	22-22	—
17.0	6.8	1.6	2.5	7.5	1.3	6.7	47°	XI-I, 15	III, 15	23-24	—
25.8	9.3	2.4	3.4	11.1	1.8	9.9	51°	XI-I, 15	III, 15	24-24	7-1-16
39.7	15.0	4.0	5.0	15.6	3.5	19.3	45°	XI-I, 15	III, 15	24-24	7-1-15
46.0	16.0	4.3	5.7	17.3	4.0	23.0	44°	XI-I, 15	III, 15	22-20?	7-1-15
57.4	18.7	5.1	6.5	22.1	4.1	29.0	43°	XI-I, 15	III, 15	22-21	7-1-14
91.2	31.0	10.3	9.4	34.3	5.5	28.3	52°	XI-I, 15	III, 15	23-23	7-1-14
117.0	36.5	9.5	12.9	44.0	6.5	48.5	52°	XI-I, 15	III, 15	22-22	7-1-14
120.5	38.2	11.3	12.3	44.1	6.5	50.5	50°	XI-I, 15	III, 15	21-22	7-1-16
147.5	46.4	12.3	14.5	54.1	8.0	56.5	53°	XI-I, 15	III, 15	23-21	8-1-14
149.8	47.0	13.9	15.3	52.0	8.5	57.0	53°	XI-I, 15	III, 15	22-22	7-1-15
183.2	62.3	18.3	17.1	68.2	10.5	70.3	51°	XI-I, 15	III, 15	22-22	7-1-15

base aligned with the straight edge of the protractor or its extension. The thread was swung to the pelvic spine and the angle read from the protractor scale. The measurement is considered to be only approximate. However, with practice, several readings could be obtained from a specimen with a variation of only 2 to 3 degrees, and usually less. A device such as described by Hubbs (1946) was too large for the smaller specimens and a microscope ocular protractor was too small for intermediate size specimens.

Counts.—Counts are total counts; taken from the left side of the specimen, unless that side was badly damaged; and are given in Table 2. Scale counts are not given because scales were lacking on most specimens. The last dorsal and anal fin rays are branched to their bases in most specimens and were counted as one ray.

Gill-raker counts are not given for all specimens since making these counts, particularly in small specimens, involved considerable damage to the head. It was felt that some specimens should be left intact.

Figures.—Figures of specimens do not show the scales. In most specimens the posterior course of the lateral line could not be traced and may not be as shown in the figures. The configuration and pigmentation of the dorsal and anal fins are partial reconstructions in most of the figures. With the exception of Figure 7d, the graphs show percentages of standard length or head length plotted against standard length or head length. Computations were made by slide rule.

Psenes regulus Poey

Figures 1-8, Tables 1-2

Psenes regulus Poey, 1868: 375 (Description; type locality, Cuba).

Psenes maculatus, Goode and Bean, 1895: 221, pl. 63, fig. 229. (See Miller, 1946, in regard to erroneous station data given on p. 221). Fowler, 1936; 664, fig. 298. (Figure 298 was taken from Goode and Bean, 1895, fig. 229 which is *P. regulus.*)

Psenes regulus, Jordan and Evermann, 1896: 951 (compiled). Regan, 1902: 127 (compiled). Smith, 1907: 223 (off Beaufort, N. C.). Miller, 1946: 208 (compiles W. Atlantic records and adds USNM records as follows: 34°38′-30″N, 75°33′30″W; 32°27′30″N, 77°20′30″W). Fowler, 1951: 57-58 (Fig. 45-50 miles SE Atlantic City, N. J.).

Three species, *Psenes indicus* (Day, 1870) from the Indo-Pacific, *Cubiceps dollfusi* Chabanaud, 1930 from the Red Sea, and *Psenes extraneus* Herre, 1950 from the Philippines, are evidently closely related to *Psenes regulus,* but definite conclusions as to their status cannot be made without reference to types.

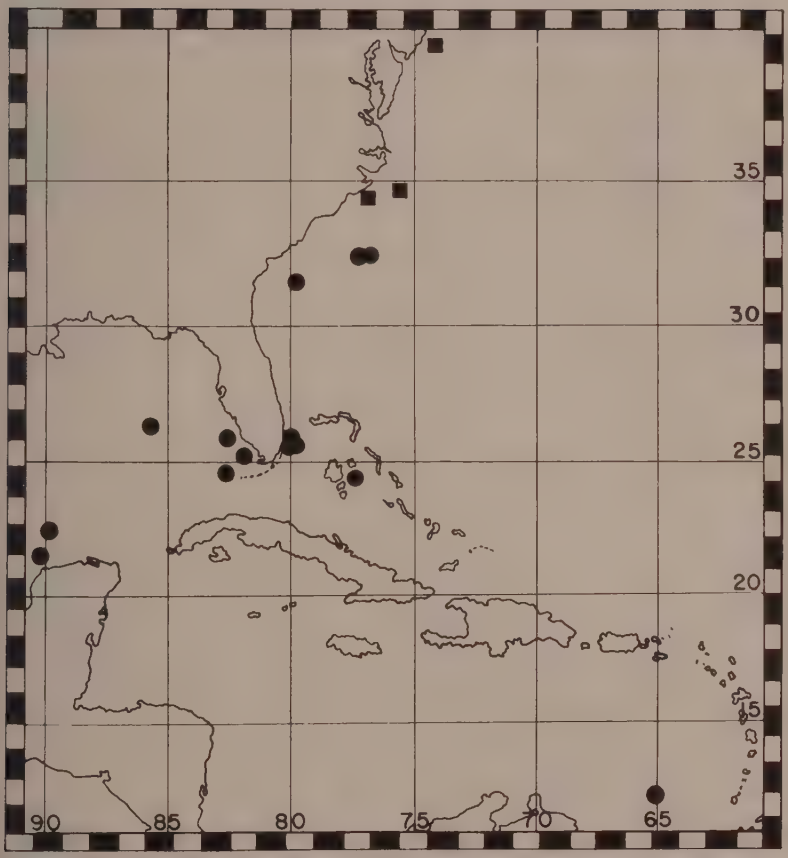

FIGURE 1. Geographical distribution of *Psenes regulus*. Circles indicate location of capture of specimens examined by the author, and squares are other records from the literature.

Psenes indicus was first described as a species of *Cubiceps* by Day (1879), but he later (1878, p. 237) placed it in the genus *Psenes*. Jordan and Evermann (1896, p. 951) considered this species a synonym of *Psenes regulus*, but Regan (1902, p. 127) did not. *P. regulus* and *P. indicus* have comparable scale counts, fin-ray counts, and body depths, but evidently differ in color pattern.

Herre (1950, p. 342) believes *P. extraneus* to be closely related to

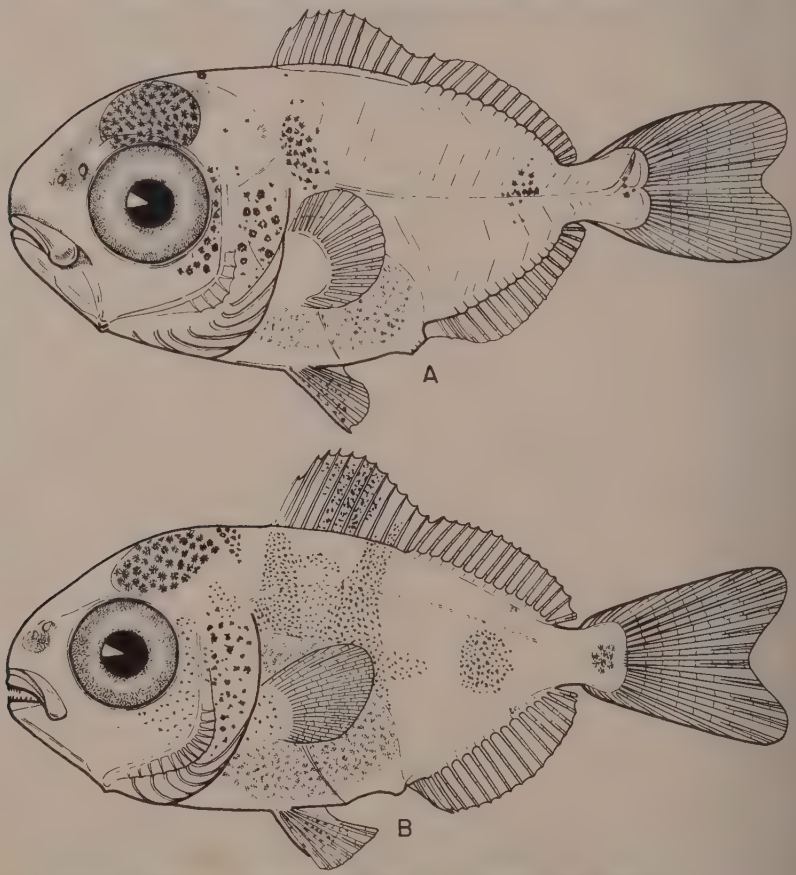

FIGURE 2. *Psenes regulus:* a - 7.0 mm, b - 10.2 mm.

P. indicus and possibly only a variation of it. *P. extraneus* is similar to *P. regulus* in scale counts, fin-ray counts and body proportions. The color pattern of the body is evidently similar, but the pelvic fins are said (Herre, 1950) to be yellow whereas the pelvic fins of *P. regulus,* at a comparable size, are black.

Chabanaud's *Cubiceps dollfusi* is also comparable to *P. regulus* in scale and fin-ray counts and body depth and apparently has an obscure, barred color pattern. This species also has low keels on the caudal peduncle.

Development

7.0 mm specimen (Figure 2a).—The smallest specimen available is a 5.3 mm postlarva too badly damaged to be the basis for an adequate description, although it was possible to obtain some counts and measurements from it. The following description is based on a 7.0 mm postlarva.

The body is deep, 48.6 percent of standard length, and compressed, although somewhat bulging in the visceral area. Posterior to the anus, the body tapers to a short, and moderately deep caudal peduncle. Scales were not seen.

The head, 44.3 percent of standard length, has a blunt snout, 25.8 percent of head length. The mouth is moderate, terminal, and slightly oblique. Teeth were not seen. Eye diameter is 42.6 percent of head length. The nostrils are paired and the preoperculum is serrated along its posterior edge. Gill rakers are well developed on the central part of the first gill arches, but not at the dorsal and ventral ends of the limbs.

Most fin elements are present and the majority are well developed. The dorsal fin, which originates above the edge of the operculum, is highest anteriorly and is continuous, although notched. There are 12 spindly spines and 15 soft rays. The anal fin is about as high as the dorsal and has three incompletely developed spines and 15 soft rays. The last spine of both the dorsal and anal fins has somewhat the appearance of a soft ray, but is not articulated. The longer dorsal and anal rays have one articulation. The urostyle is well developed and the caudal fin is slightly forked. The anterior portions of both caudal lobes have developing elements. The pectoral fins are short and rounded and the left has more than 18 elements. The short pelvics have one spine and five soft rays. The pelvic angle is 29°.

In fresh specimens there is a heavy pigmentation by large chromatophores in the cranial area. The sides of the head behind the eye have scattered chromatophores, and the visceral area is pigmented except in its more ventral and posterior parts.

There are three pigment groups along the sides in addition to the pigment in the visceral area. The first of these groups is the most extensive and lies between the origin of the dorsal fin and the visceral pigment area. The second group is about midway between the dorsal and anal fin bases at their posterior ends. The third, and smallest, pigment group is at the caudal base and consists of only four or five

chromatophores. There are a few chromatophores on the pelvics, but none on the other fins. All chromatophores were black when the specimen was fresh, but have faded to brown.

The badly damaged 5.3 mm specimen is much like the above specimen, but exhibits some differences. The anterior part of the dorsal fin is lower than the posterior part in contrast to the larger specimen. The pelvic angle is only 17° and the pelvic fins are not pigmented. The three groups of chromatophores along the sides are less extensive than in the larger specimen.

10.2 mm specimen (Figure 2b).—A postlarva of 10.2 mm shows several developmental changes. Body depth has decreased slightly to 45 percent of standard length. Cycloid scales can be seen and 31 lateral-line scales with tubes were counted to just below the last dorsal soft ray.

Although head length and eye diameter show little proportional change, head shape has changed. The top of the head slopes more steeply to the snout, but the snout remains blunt. There are small pointed teeth on both jaws and the nostrils are well developed.

All fins are relatively larger. The soft dorsal and anal fins have more rounded margins and the last soft rays in both fins are branched. The last dorsal- and anal-fin spines no longer have the appearance of soft rays. The caudal fin, although damaged in this specimen, can be seen to have straighter dorsal and ventral margins and is more deeply forked than before. The longer caudal rays have eight articulations. The pectorals are more tapered. The pelvic fins are larger and the pelvic angle is 34 degrees.

Pigment has appeared in new areas, and the pigmented areas present in the 7.0 mm specimen are more extensive and dense. The spinous dorsal bears pigment in its central portion and pigment on the pelvic fins has increased. The pigmented area between the dorsal fin base and the visceral area is now composed of two bars; the posterior of these bars extends onto the dorsal fin. A new pigment spot has appeared on the side posterior to the visceral area and is followed by the two spots noted in the 7.0 mm specimen which are larger and more dense. There are two or three chromatophores at the bases of the soft dorsal and anal fins. Head pigmentation is about the same except for a few chromatophores on the jaws.

16.4 mm specimen (Figure 3a).—At 16.4 mm the animal is more

slender. Body depth is only 40.7 percent of standard length and the caudal peduncle is more slender than in the preceding specimens.

The head, besides being less deep, has more rounded contours than the smaller specimens. Head length has decreased slightly, and eye diameter in relation to head length has decreased considerably. The preoperculum is less deeply serrated.

The fins are relatively larger, except for the caudal which is slightly smaller, but more deeply forked. The dorsal is more deeply notched, but still continuous. The pectorals are more elongate and the pelvic angle is 41 degrees.

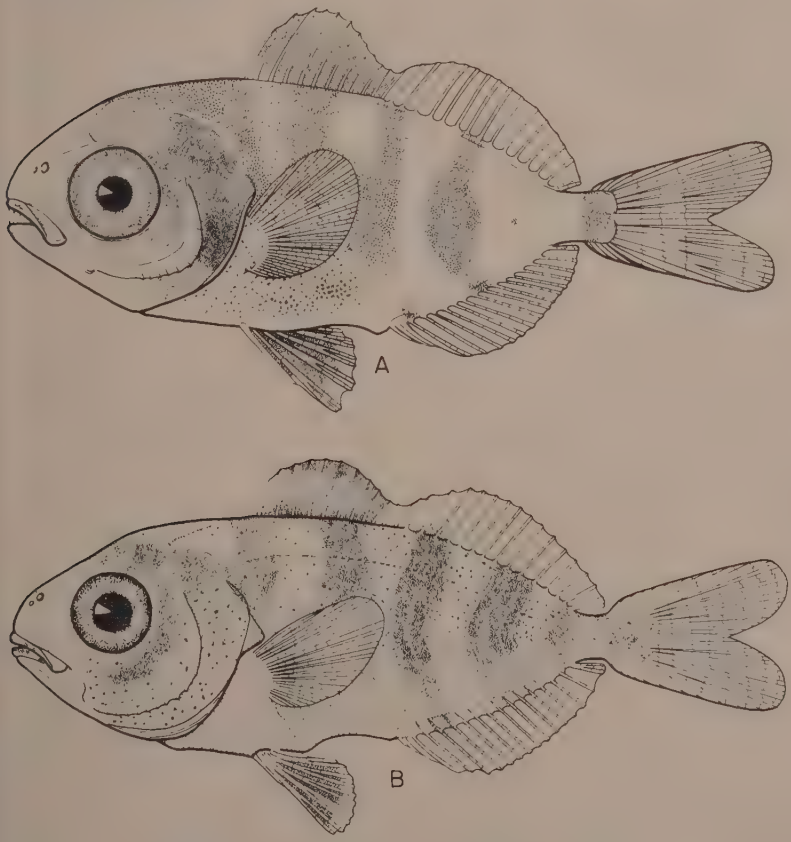

FIGURE 3. *Psenes regulus:* a - 16.4 mm, b - 25.8 mm.

In this specimen a more definite pigment pattern can be discerned consisting of four bars and a spot on the caudal peduncle. The first two bars, just above the visceral area, merge with the pigmentation of this area ventrally, but are quite well defined dorsally. The third bar, beneath the anterior part of the dorsal fin, and the fourth bar, beneath the middle of the soft dorsal fin, are expanded in their central portions. Between the fourth bar and the last bar on the caudal peduncle, is a small pigment spot. The head posterior to the eye is heavily pigmented, especially on the preoperculum and operculum. The underside of the head and the belly are unpigmented. The snout has a few chromatophores anteriorly and near the mouth. The spinous dorsal fin is heavily pigmented for about two thirds of its height. The pelvics have a colorless border.

25.8 mm specimen (Figure 3b).—Although this specimen is about 9 mm larger than the preceding specimen, its body depth has decreased only about two percent. Head length has decreased to 36 percent of standard length, but eye diameter in head length has not changed appreciably. The spinous dorsal fin is not so high in relation to the soft dorsal fin as it previously was and the bases of the soft dorsal and anal fins are scaled. The pectoral fins are more tapered and the pelvic fins are relatively longer. The pelvic angle has increased to 51 degrees.

The pigment pattern consists of five well defined bars, with evidence of a sixth forming in the region of the eye, and a spot at the caudal base. A background pigmentation makes the body quite dusky, except for the snout which is still almost colorless. The pelvics retain their colorless border and the spinous dorsal fin is heavily pigmented. Some pigment is now present at the bases of the soft dorsal, anal, and caudal fins.

This 25.8 mm specimen (USNM 174979) is somewhat isolated in this series, both from the point of view of its appearance and the lack of specimens between this stage and the next specimen in this series (39.7 mm, UMML 2460).

Since, as is explained below, there are species recorded from the Western Atlantic which the author believes are fairly closely related to *Psenes regulus,* there may be reason to doubt the identity of this specimen as *P. regulus.* These other species, *Cubiceps nigriargenteus* Ginsburg, 1954, *Cubiceps melanus* Ginsburg, 1954 and *Ariomma bondi* Fowler, 1930, have meristic characters either close to, or iden-

tical with, *P. regulus,* but known specimens of these species differ from *P. regulus* in being more slender and in lacking a color pattern such as that found in *P. regulus*. It may be possible to separate *P. regulus* and *A. bondi* from the species of *Cubiceps* mentioned by gill-raker counts. According to Ginsburg's material the raker counts for *C. nigriargenteus* are 26-29 and for *C. melanus* they are 27-31. The author's material of *P. regulus* has raker counts of 22-24. Fowler recorded 23 rakers for *A. bondi*.

The young stages of these other species are unknown. The larval-fish collections at the Marine Laboratory have only two specimens that may be of one of these three species. They were taken in the Florida Current off Miami and are 23.9 mm and 29.5 mm standard length. The body depth of the smaller is 29.3 percent of standard length and that of the larger is 28.8 percent. Neither have any trace of a barred or spotted pigment pattern. Both are pale brown with dark brown backs. Counts are as follows (those of the larger specimen in parenthesis): D, XI-I, 16 (XI-I, 15); A, III, 15 (III, 15); pectorals, 21 (22); gill rakers, 25 (23). The meristic characters, therefore, will not identify these specimens; however, the author believes that color pattern and body depth exclude them as specimens of *P. regulus*.

If this 25.8 mm specimen does not prove to be *P. regulus,* then the smaller specimens in the series probably are not *P. regulus* either. However, the author feels that this specimen belongs in this series for the following reasons: (1) If pigmentation alone is considered, the specimen fits neatly into the series. (2) Body proportions of this specimen, even though exhibiting marked differences in regard to the succeeding specimen in this series, especially in body depth, fits into the pattern of development as far as can be determined from specimens available. This is true not only with body depth, but with other body proportions as well.

39.7 mm specimen (Figure 4a).—Between 25.8 mm and 39.7 mm a striking increase in body depth has occurred. Depth is now 48.7 percent of standard length, and, although almost the same as that of the 7.0 mm specimen, the outline of the two stages is quite different. This is due to the larger specimen tapering more sharply anteriorly and posteriorly than the smaller one.

Although head length in standard length and snout length in head length have changed only slightly, the snout is even more blunt appearing than in former specimens. The dorsal fin is now so deeply

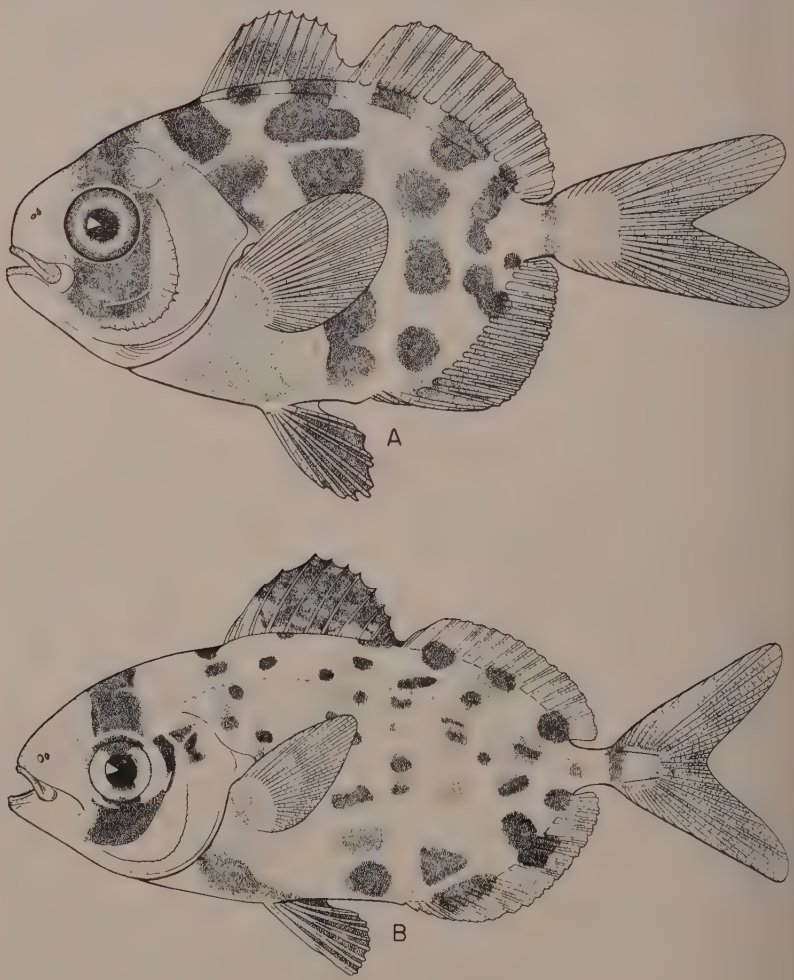

FIGURE 4. *Psenes regulus:* a - 39.7 mm, b - 91.2 mm.

notched as to be almost divided and all of the fins except the caudal and pectoral fins are relatively larger. The pelvic angle has decreased to 45 degrees.

The barred pigment pattern is still present, but the bars are breaking up into large blotches and there is a bar running through the eye.

The spot on the caudal peduncle has become diffuse. The snout is still only lightly pigmented. The underparts of the head and body are white. A background pigmentation is present on the sides of the body except for the posterior ventral quarter. All fins bear some pigment. The dorsal and anal fins are dusky and the pelvic fins are now completely pigmented.

57.4 mm specimens (No figure).—This specimen shows some changes in body proportions, but in most respects is a larger and slightly elongated version of the last specimen. Depth has increased only slightly, but the dorsal and anal profiles are more nearly parallel, giving the specimen a more elongate appearance.

Head length has decreased to 32.6 percent of standard length and a narrow adipose eyelid is present. The bases of the soft dorsal and anal fins are more extensively scaled than previously.

The pigment pattern on this specimen is faded, but from what can be seen it is much like that of the last specimen and that of Figure 229, Plate 63 in Goode and Bean (1895). As Miller (1946) observed, this figure is of a specimen of *Psenes regulus* and not *Psenes maculatus* as labeled.

91.2 mm specimen (Figure 4d).—This specimen is about the size of that figured by Fowler (1951). Body depth has decreased to 42 percent of standard length. The caudal peduncle is not only more slender than in previous specimens, but it also bears two very low keels on each side. These are at the bases of the caudal fin lobes and converge posteriorly. Head length in standard length and eye diameter in head length have decreased slightly.

The soft dorsal and anal fins are considerably lower than previously. Both the pectoral fins and the caudal fin are more tapering and have stiffer rays. The caudal is more widely forked. The pelvic angle has increased to 52 degrees.

Aside from some postlarval specimens, this specimen and one 117.0 mm standard length were the only ones examined while still fairly fresh. Although scales were missing from both specimens, some idea of their coloration in life could be obtained.

The tendency for the barred pattern to break up into blotches is even more evident. In the 91.2 mm specimen, and to an even greater extent in the 117.0 mm specimen, there is a tendency for the blotches to break up into spots dorsally, but the ventral blotches are beginning

to disappear and many are represented only by dusky smudges in the larger specimen.

The background color of the entire body is silvery white. The blotches and spots on the body and soft-dorsal, and anal fins, and the spinous dorsal and pelvic fins are black (possibly purple or deep-blue in life). The eye has a golden iris with flecks of black in it and the pupil is black. The bar which runs through the eye can be seen on the iris. The interior of the mouth is pale and the snout has a very diffuse pigment, but is somewhat dusky.

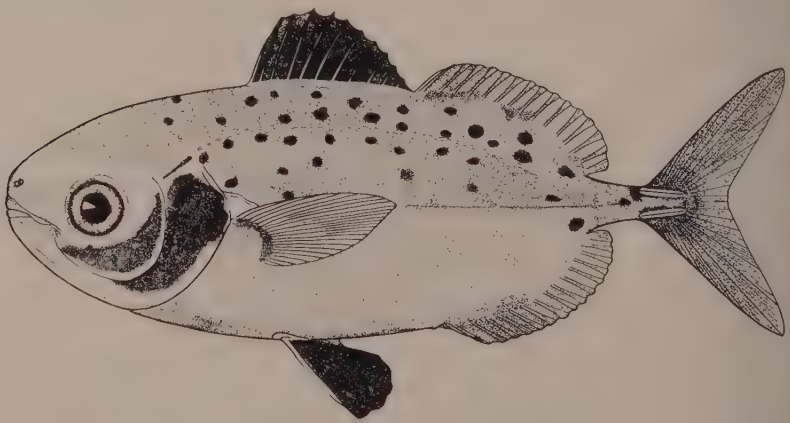

FIGURE 5. *Psenes regulus:* 183.2 mm.

183.2 mm specimen (Figure 5).—This specimen is the largest one available to the author and is a mature female; ripe enough so that handling the preserved specimen caused eggs to be extruded.

The body shape is that of an elongate ellipse. Body depth is 38.3 percent of standard length and eye diameter has decreased to 27.6 percent of head length.

The snout is blunt and covered with a thick layer of fleshy tissue which has many pores. The thick and extensive adipose tissue around the eye is continuous with the snout tissue anteriorly. The keels on the slender caudal peduncle are better developed than in the 91.2 mm specimen, but are low.

The spinous- and soft-ray portions of the dorsal are discontinuous with a count of XI-I, 15. The first dorsal is the higher and both the second dorsal and the anal fins have well scaled bases. The first dorsal

can be depressed into a groove as can the pelvic fins. The pectoral fins and the caudal lobes are stiff and taper to a point. The pectorals are covered with a fleshy tissue. The pelvic angle is about the same as before.

The background color of this preserved specimen is generally brown and somewhat darker dorsally. There is evidence of a white or silver coloration at the base of the anal fin, but the specimen is so abraded that it is impossible to determine how extensive this white pigment was in life. All that remains of the barred pigment pattern is a scattering of small dark spots on the dorsal half of the body. The spinous dorsal and pelvic fins, and the preopercule and opercule are black.

Summary of development.—The pigment pattern starts as a series of spots made up of large chromatophores. These spots eventually develop into a barred pattern which gradually breaks up into blotches. These blotches in turn break up into small spots which are present dorsally in the adult. The ventral blotches become diffuse and traces of them are vague in the three largest specimens. There are more dorsal spots on specimens 117.0 mm to 149.8 mm standard length than on the larger specimen.

Pigment appears on the spinous dorsal and pelvic fins at about 10

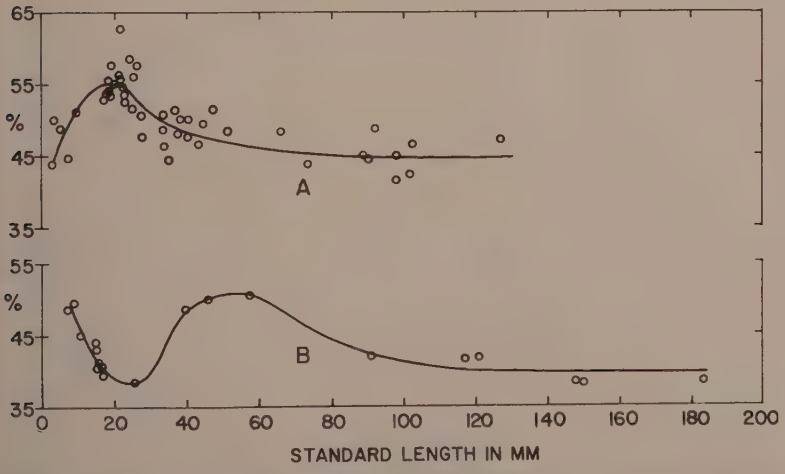

FIGURE 6. Change of body depth during growth in relation to standard length. a - *Psenes cyanophrys,* b - *Psenes regulus.*

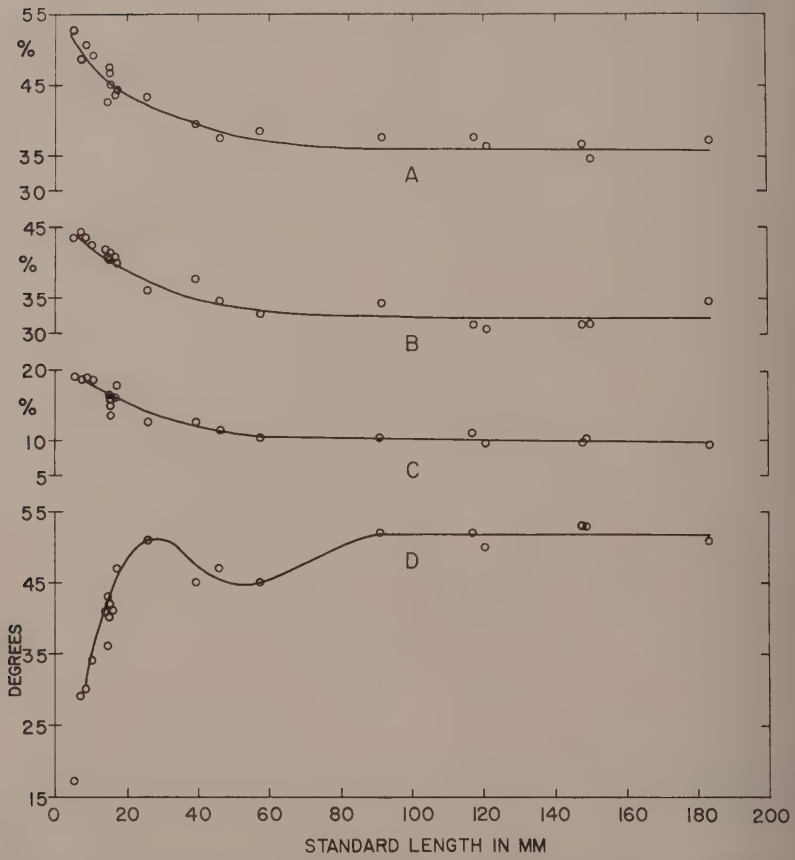

FIGURE 7. Changes of body proportions in *Psenes regulus* during development in relation to standard length. a - predorsal length, b - head length, c - eye diameter, d - pelvic angle in degrees.

mm standard length. The spinous dorsal is variously blotched until the animal is about 100 mm standard length and then becomes black. The pelvics have a colorless border until the animal is between 30 and 40 mm standard length, and then becomes entirely black.

The small number of specimens available and size gaps in the series do not permit a precise demonstration of the changes in body pro-

portions during growth; however, certain general features may be presented.

Depth decreases from about 50 percent of standard length in the smallest specimen to about 39 percent in the 25.8 mm specimen. Then depth increases to 50 percent again and levels off at 38 to 42 percent in specimens larger than the 91.2 mm specimen. (See Figure 6d.) Caudal peduncle depth in body depth and standard length (neither of which is figured) shows a trend similar to that of depth in standard length, but the peaks of the curves and their fluctuations are not as distinct.

The pelvic angle when plotted against standard length (Figure 7d) shows a trend almost the reverse of that of depth in standard length.

Head length in standard length (Figure 7b) decreases until the animal is about 60 mm standard length and then levels off to 30 to 35 percent. Orbit length and predorsal length in standard length (Figures 7c, 7a) follow a similar pattern. Orbit length in head length (Figure 8a) decreases from the smallest specimen in the series to the largest, but perhaps would be found to level off at about 90 mm standard length if more large specimens were available.

Snout length in head length (Figure 8b) is similar to body depth in standard length, but does not level off until a head length of 45 to 50 mm which is equivalent to specimens 147 to 150 mm standard length.

The two dorsal fins are distinct even in small specimens, but do not

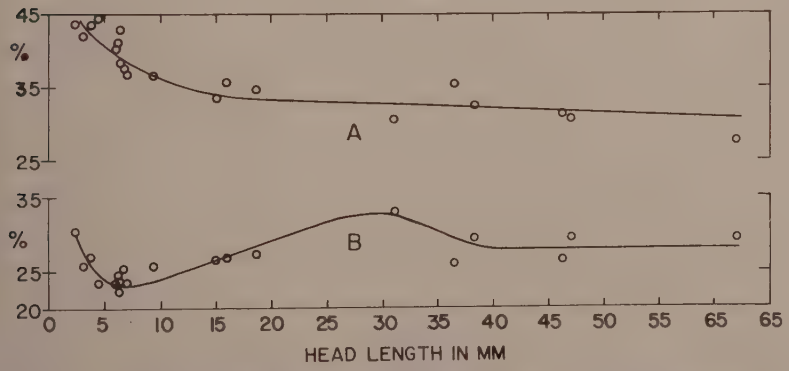

FIGURE 8. Changes of body proportions in *Psenes regulus* during development in relation to head length. a - eye diameter, b - snout length.

become discontinuous until a size of more than 91.2 mm standard length. The pectorals are rounded in outline at first, but became falcate at about 91.2 mm standard length when the caudal fin also becomes falcate and stiff.

Scales are present, but are easily lost and are largely missing from most specimens examined. The author would estimate that there are 50 to 60 scales in the lateral line to the caudal base. In most specimens it was impossible to trace the course of the lateral line on the caudal peduncle.

The keels on the caudal peduncle can be seen on specimens as small as 91.2 mm, but even in the largest specimen they are low.

Hubbs (1944 and 1958) has proposed terms for the developmental stages of fishes. Using this terminology the author would divide this series as follows: 5.3 to 10.2 mm - postlarvae, 14.1 to 25.8 mm - prejuveniles, 39.7 to 117.0 mm - juveniles, 120.5 to 183.2 mm - adults.

Comparison of Changes in Body Depth During Growth of *Psenes regulus* and *Psenes cyanophrys*

Figure 6 compares changes in body depth during the growth of *Psenes cyanophrys* Valenciennes and *Psenes regulus*. When making comparisons between species such as this it is desirable to compare similar developmental stages, rather than simply comparing specimens of approximately equal sizes. In this case the author has no specimens of *P. regulus* below 5.3 mm standard length, nor does he have specimens, or data on specimens, of *P. cyanophrys* larger than 125 mm standard length. However, within the size range where both species are available, the similar sizes seem to correspond fairly well to similar developmental stages.

Data for the specimens of *P. cyanophrys* are taken directly from Legaspi (1956), with the exception of some data from specimens taken in Florida and Bahamian waters which have been added by the author. Legaspi's data have been plotted on the same scale as the data for *P. regulus* for comparison.

Psenes cyanophrys increases in relative body depth to a standard length of about 20-25 mm and then becomes more slender until a size of 30-40 mm when depth in standard length levels off to a value of about 40 to 50 percent. Relative body depth in *Psenes regulus* decreases from about 5 mm to 26 mm standard length and then shows a marked increase to a size of 50 mm to 60 mm; then decreases to a

body depth which is apparently lower than that of *P. cyanophrys* in the larger stages. There also seems to be more variation in body depth at all stages in *P. cyanophrys,* although this could result from the larger series of specimens available for *P. cyanophrys.*

Head length in standard length and snout length in standard length follow similar patterns in both species for the sizes where comparison is possible.

Eye diameter in standard length is fairly constant in *Psenes cyanophrys,* but shows a tendency to decrease until a size of about 60 mm standard length in *Psenes regulus.*

Snout length in head length gradually decreases until a standard length of about 10 mm in *P. cyanophrys,* but follows a pattern similar to body length in standard length in *P. regulus.*

Distribution and Biology

Geographic distribution.—Disregarding the possible synonymy of *Cubiceps dollfusi* Chabanaud, *Psenes extraneus* Herre, and *Psenes indicus* (Day) with this species, all records of *Psenes regulus* known to the author are from the Western North Atlantic, including the Gulf of Mexico and the Caribbean Sea. Specimens have been taken as far south as 12° North latitude in the Southeastern Caribbean to as far north as off the coast of New Jersey. The larger specimens have been taken in areas suggesting that the species is essentially tropical and that northern records are of animals carried, or moving, north in the Florida Current. (See Figure 1.)

Vertical distribution.—No specimen was taken by gear that permits an accurate estimation of depth of capture. The only reliable record of depth seems to be that of two specimens taken by the ALBATROSS off Cape Lookout, North Carolina, at the surface. With the exception of one 39.7 mm specimen taken over water of 64 meters depth, the available data indicate that specimens less than 91.2 mm standard length were taken where water depth was at least 200 meters and most were taken where water depth was more than 500 meters. Specimens 91.2 mm or larger were taken where water depth was 25 meters to 77 meters.

Eggs and spawning.—The largest specimen in this series is a female; ripe enough so that handling the preserved specimen caused eggs to be extruded. Preservation has probably altered these eggs, but 51 were measured. They range from 0.90 mm to 1.18 mm in diameter with

an arithmetical average diameter of 1.02 mm. All eggs have golden-brown oil globules. Some have one globule about 1/6 to 1/4 the egg diameter and in others there are several smaller globules. The natural condition is not known.

This female was taken in September and young specimens from 5.3 mm to 25.8 mm standard length were taken in January, April, and May of four different years. These admittedly sparse data indicate a long-term spawning throughout the fall, winter, and spring.

Associations.—Several specimens have been taken by shrimp trawlers on the Tortugas Ground, but are evidently not common there for the fishermen did not recognize them. There is some evidence that these fish may school, since at least one shrimper picked up "a whole lot" in one haul. Unfortunately only two or three were saved.

There do not seem to be any records of this species in association with floating objects, as is common for *Psenes cyanophrys,* nor in association with jellyfish as is known for *Icticus pellucidus, Psenes maculatus, Nomeus gronovii,* and some other stromateoids.

Classification

Miller (1946, p. 209) in commenting on "psenid" fishes in the U. S. National Museum, noted three groups: a *pellucidus* group, a *cyanophrys* group, and a *"maculatus"* group. He also remarked that *Psenes regulus* did not seem to be very closely related to any of these groups due to its low fin-ray counts and its coloration. This conclusion is confirmed here.

Aside from differences in fin-ray counts and coloration, the development of *Psenes regulus* is quite different from that of the type species, *Psenes cyanophrys,* especially as regards changes in body depth during growth. Other differences are present in large specimens of *P. regulus.*

The largest specimen of *P. cyanophrys* that the author has knowledge of is about 125 mm standard length. This specimen was examined by Robins and Berry at the U. S. Fish and Wildlife laboratory at Brunswick, Georgia. The author has specimens almost as large from the Marine Laboratory collections. The caudal peduncle is relatively deep, the caudal fin is relatively soft and not widely forked. There are no keels on the caudal peduncle. Large specimens of *P. regulus* have a slender caudal peduncle bearing a pair of low keels on either side and a stiff, widely forked caudal fin.

The low fin-ray counts of *Psenes regulus* and the features of its

caudal region are much like species of *Cubiceps* described by Ginsburg (1954), and Chabanaud (1930) and a species described by Belloc (1937). Ginsburg only tentatively allocated *Cubiceps nigriargenteus* and *Cubiceps melanus* to the genus *Cubiceps* Lowe 1843. Belloc erected a new genus for his species, *Paracubiceps ledanoisi* (misspelled *"ledenoisi"* in the paper's title).

The literature and the few specimens that the author has examined indicate that there are at least two groups, and possibly more, currently placed in the genus *Cubiceps*. One group is represented by *Cubiceps gracilis* (Lowe, 1943) and another by species such as *Cubiceps nigriargenteus, Cubiceps melanus,* and *Cubiceps dollfusi*. In addition there are species such as *Paracubiceps ledanoisi* which have been placed in other genera, but which are obviously closely related to *C. nigriargenteus* and *C. melanus*.

Dr. N. B. Marshall has examined specimens of *Cubiceps gracilis* in the British Museum and reports that he finds no keels present on the caudal peduncle and that the body tapers gradually to the peduncle which is quite stout. Fin-ray counts for *C. gracilis* are usually reported as being considerably higher than the fin-ray counts for *C. nigriargenteus, C. melanus, C. dollfusi, Paracubiceps ledanoisi,* and *Psenes regulus*. Koefoed (1952), for example, gives counts for 31 specimens of *C. gracilis* as follows: D_1.XI, D_2.I21-23, A.III19-21.

Dr. John E. Randall examined the type specimen of *Ariomma lurida* Jordan and Snyder, 1904, the genotype of *Ariomma;* and the type specimen of *Cubiceps melanus* while at the U. S. National Museum. He reports that both have slender caudal peduncles bearing two low keels on either side. Ginsburg's figure of *C. nigriargenteus* (Ginsburg, 1954, Figure 3) indicates keels on the caudal peduncle, although the text does not mention them.

Jordan and Snyder (1904) give the dorsal and anal-ray counts for *Ariomma lurida* as: "dorsal spines, 10; rays, 17; anal, 15," but also state that the specimens were in a bad state of preservation and the fins broken. Katayama (1952) gives a dorsal fin count of XI, 16 and an anal count of II, 15 for a specimen from Japan. Abe (1954a) reports that two other specimens from Japanese waters have dorsal counts of XI, I15 and XII 15 and anal counts of II 15.

Belloc (1937) describes *Paracubiceps ledanoisi* as having fin-ray counts of D:X-15 or 16, A:III, 15 or 16, and P:20. The species has a slender caudal peduncle bearing two low keels on either side, but lacks

an adipose eyelid. This last feature is mentioned in relation to the difference of this species from *Trachurops* (= *Selar*) *crumenophthalmus* (Bloch) which has an extensive adipose eyelid.

Cubiceps dollfusi has many features in common with *P. regulus.*

Psenes regulus, Cubiceps dollfusi, Cubiceps nigriargenteus, Cubiceps melanus and *Paracubiceps ledanoisi* differ from *Ariomma lurida* mainly in having shorter heads, smaller eyes, and less well developed adipose eyelids (in *A. lurida* adipose tissue covers almost the entire posterior half of the eye). There may also be differences in the number of spinous elements in the dorsal and anal fins, although these differences could also be due to difficulty in locating the last spinous elements of the first dorsal fin and the first spinous element of the anal fin which are small in specimens examined by the author. In addition to these differences, *Psenes regulus* and *Cubiceps dollfusi* differ from the other four species in coloration and body depth.

In view of the above, the author believes that these five species, *Psenes regulus, Cubiceps dollfusi, Cubiceps nigriargenteus, Cubiceps melanus* and *Paracubiceps ledanoisi,* should be placed in the genus *Ariomma.* The differences among them are mainly differences of degree, and the similarities, especially of the caudal region, are significant characteristics shared by all four and by the type species of *Ariomma,* but not by the type species of *Psenes* and *Cubiceps.*

A group comopsed of *Cubiceps nigriargenteus, Cubiceps melanus, Paracubiceps ledanoisi, Ariomma bondi,* and apparently similar species from regions other than the Atlantic, probably includes synonyms. Specimens of this group in the Marine Laboratory collections could be attributed to more than one species based on the descriptions and giving regard to size differences and condition of the specimens on which the descriptions are based. However, definite conclusions cannot be made without examination of the types.

The possible synonymy of *Cubiceps dollfusi* and other species with *Psenes regulus* has been mentioned.

The classification of the stromateoid fishes is confused and unsatisfactory. This seems to be true not only at the specific level, but also as regards the higher categories. Changes occurring during growth and the limited number of specimens available to any one worker are factors contributing to this confusion. A complete revision of this group involving such genera as *Psenes, Cubiceps, Ariomma, Paracubiceps, Nomeus* Cuvier, 1817, and *Icticus* Jordan and Thompson,

1914, and their synonyms, as currently understood, may not show that *Ariomma* has a valid basis. Jordan and Jordan (1922, p. 35) doubted that *Ariomma* differed from *Cubiceps* Lowe and prior to this Jordan and Evermann (1896, p. 950) had placed *Cubiceps* in the synonymy of *Psenes*. However, the author believes that under the present conditions the genus *Ariomma* is at least useful since it can be used to bring together species having more characters in common with one another than with species of the genera in which they are currently placed, or, as is the case with *Paracubiceps ledanoisi*, have had a new genus erected for them which is based on these same characters.

Probably there are other species in various genera with as much reason for being placed in this genus as the four allocated to it in this paper, but the author hesitates to do this without more information concerning them than he now has available. Some species currently placed in the genus *Cubiceps* Lowe probably do not belong in it, nor in the genus *Ariomma* Jordan and Snyder. Specimens of *Cubiceps ismaelensis* Dieuzeide and Roland, 1955, for example, should be compared with specimens of equal size of *Icticus pellucidus* (Lütken) 1880, or *Icticus ischanus* Jordan and Thompson, 1914 which is suspected of being a synonym of *I. pellucidus* by Abe (1954 and 1954a) and Tomiyama (1954).

Summary

1. Materials utilized and methods of study are described. Larval, prejuvenile, juvenile, and adult specimens of *Psenes regulus* can be separated from other psenid fishes by dorsal and anal fin-ray counts and coloration and are probably separable from other related species in the Western North Atlantic by coloration and body proportions.

2. Previous references to *Psenes regulus* and possible synonyms are listed.

3. A developmental series of 21 specimens from 5.3 mm to 183.2 mm standard length is described and seven specimens are figured.

4. Indices and graphs showing various morphological changes associated with growth are presented. Some of these are compared with similar graphs of Legaspi (1956) which show developmental features of *Psenes cyanophrys*.

5. Geographical and vertical distribution, spawning, and associations of *Psenes regulus* are briefly discussed.

6. Comparisons of *Psenes regulus* with *Psenes cyanophrys,* in regard to development and adult characters, indicates that *P. regulus* probably does not belong in the genus *Psenes.*

7. *Psenes regulus, Cubiceps dollfusi, Cubiceps nigriargenteus, Cubiceps melanus,* and *Paracubiceps ledanoisi* are allocated to the genus *Ariomma.* The reasons for this are discussed.

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SHRIMPS THAT CLEAN FISHES[1]

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ABSTRACT

The symbiotic habits and color patterns of six species of caridean and stenopodidean shrimps that remove external parasites from fishes are described and discussed.

INTRODUCTION

Certain species of small, brightly colored shrimps have been observed to remove and eat parasites, injured tissue, and possibly undesirable food particles from a large variety of coöperating reef fishes. This symbiotic behavior is so well developed in some cases that the shrimps are invited to enter the mouths and gill cavities of their hosts, apparently with complete immunity from being eaten.

In many areas these shrimps, which are seldom abundant, seem to be the key organisms in small ecosystems. They are, together with certain fishes that also clean, seemingly responsible for the control of gill, oral, and external parasites of the various reef fishes. These reef fishes, in turn, to a large extent control directly or indirectly the biological environment surrounding reefs. In a field experiment conducted in the Bahamas by the senior author, the cleaner shrimps and fishes were removed from two isolated coral heads in the area under investigation. The observed result within a few weeks was a reduced number of reef fishes and a high incidence of fishes with frayed fins and ulcerated sores. Admittedly, the experiments because of their gross nature were not well controlled, but the observed

[1]This study developed from observations made and recorded on motion-picture film in the Bahamas by one of the authors (Pederson), beginning in 1952. In the following year, that author and his brother, Verne, determined that fishes frequent established cleaning stations to have their parasites removed, and, in 1954, he first observed and recorded the cleaning of fishes by a shrimp, *Periclimenes pedersoni*. In 1956, the senior author undertook an extensive investigation of cleaning relationships in the Bahamas, as well as at Manzanillo, Mexico; Clipperton Island; and off San Diego, California. The observations recorded here were made almost exclusively by the senior author, and the paper has been only slightly revised, posthumously, from a manuscript prepared by him. Many of those who have generously contributed to the final draft are mentioned at the end of the paper, but special acknowledgment must be made of the enthusiastic and tireless assistance received from Howard M. Feder of Hartnell College, Salinas, California; without his help and encouragement, the publication of the paper would certainly have been greatly delayed and possibly neglected.

contrast with the fish populations of the nearby coral heads was very striking.

Most cleaning shrimps locate in areas that are most likely to be utilized or observed by the majority of fishes on a small reef or section of a larger reef. Often they associate with fishes that clean. The reef fishes in turn frequent these particular areas or make special trips to these shrimp cleaning stations. The latter behavior is particularly characteristic of heavily parasitized or injured fishes.

Various behavior displays and mannerisms are often utilized by both the shrimps and the fishes to attract one another. The bright colored shrimps lash their conspicuous antennae and sway back and forth on prominent points of coral or rock. The fishes display color changes, move slowly to the shrimps, and gently extend fins and gill covers, open their mouths, and in some cases elevate their barbels.

This interesting cleaning behavior must be widespread in the marine environment judging from the known distribution of the shrimps involved. It occurs in both the Atlantic and Pacific Oceans, particularly in the tropical regions. Two species of cleaning shrimps are common to both the tropical Atlantic and the Indo-Pacific. Three species are known only from the tropical western Atlantic, and a single species is endemic to the temperate waters of the Southern California Province, where none of the other five species occur.

The shrimps thus far identified as cleaners belong to six species, two in each of three genera which are placed in three families and superfamilies and in two distinct sections of the decapod suborder Natantia (Figure 1). The similar behavior patterns and the similar prominent antennae of the various species suggest that cleaning, at least at the family level, is probably the result of convergent evolution. The similarity of the behavior patterns to those of fishes, such as territoriality and the tendency to pair, may also represent convergence.

The known cleaner shrimps may conveniently be divided into two groups on the basis of behavior, habitat and color. The five species comprising one group are usually solitary or paired (although *Periclimenes yucatanicus* and *P. pedersoni* are occasionally found in small aggregations of five or six). All five species are territorial and remain for weeks and, in some cases, months or possibly years within a meter or less of the same spot. They are omniverous to a slight extent but seem to be highly dependent upon their hosts for food. This group is tropical, and the individuals are brightly marked. They

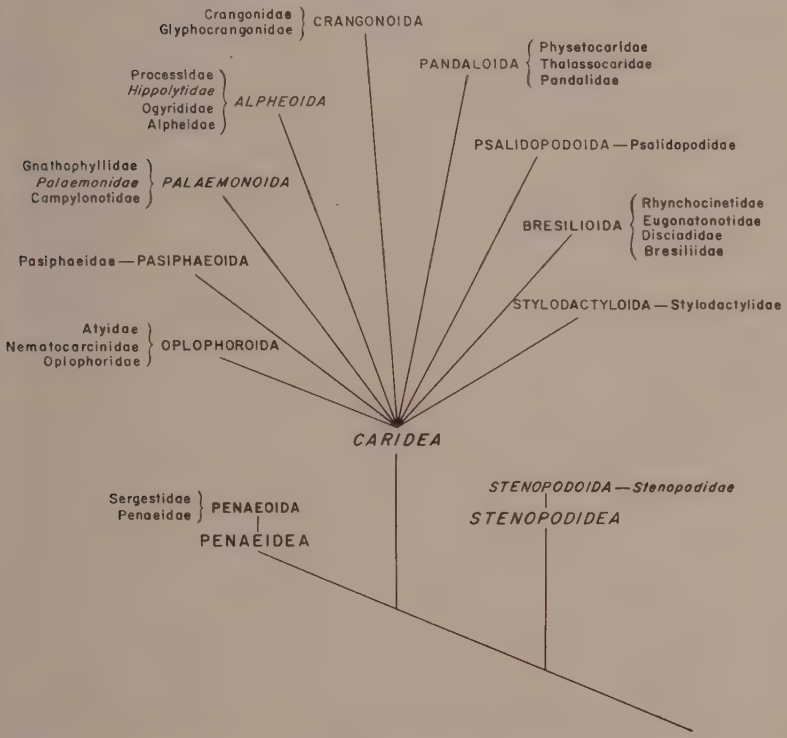

FIGURE 1. Schematic arrangement of the sections, superfamilies, and families of shrimps (Natantia) showing the relationship between the groups (in italics) containing species that clean fishes.

display themselves to their hosts in a conspicuous manner. They probably rarely serve as prey for fishes. A single species, *Hippolysmata californica,* comprises the second group. The imperfect relationship with one of the host species, in which the shrimp is sometimes eaten, suggests that this is a primitive type of cleaning behavior. This species is a gregarious, wandering, omniverous animal which occurs in cooler waters and is not highly dependent upon its host for survival. So far as is known, it does not display itself to attract fishes.

Among these cleaner shrimps there exist considerable differences in behavior, morphology, and habitat even within a genus. These differences make it necessary to consider each species separately.

Individual species

Family Palaemonidae
Subfamily Palaemoninae
Periclimenes (Periclimenes) yucatanicus (Ives, 1891)
Figure 2

This is a small species, usually less than three centimeters in body length. The antennae are longer than the body. The body and legs are smooth.

The body is transparent except for several distinct, large, white and tan saddles and spots. There is a large saddle of light tan bordered with white on the carapace. A pair of smaller light tan spots is situated on the dorsal surface of the second abdominal somite; a similar, smaller spot on each lateral surface of that somite; and one or two white spots anterior to the lateral spot. There is a large dorsal saddle on the third somite at the bend of the abdomen, and a smaller saddle on the fifth somite. At the base of the telson, a white saddle blends into a purple spot on either side. A row of white dots marks the ventral midline of the abdomen. The eyes are white, tipped with red. The eyestalks have a fine stippling of red and white dots which extends over the rostrum and the anterior part of the carapace and onto the antennular and antennal peduncles. The outer flagella of the antennules are white with an extended orange saddle at their bases. The inner flagella of the antennules are transparent with bands of red. The antennal flagella are usually banded with red and white, but the red bands may be absent. The third maxillipeds are white banded with purple. The smaller chelipeds are banded with purple and white. The larger chelipeds are banded with white, purple, red, and orange. The walking legs are purple banded with white. The uropods are tipped with reddish violet bordered proximally with white. The eggs are translucent brown. In general, this shrimp is somewhat less conspicuous in its normal habitat than are the other tropical cleaners.

This species is apparently widely distributed between southern Florida and Colombia (Holthuis, 1951). We observed it off the Bahamas, Virgin Islands, and Puerto Rico. Females with eggs were seen in July and August.

We always found it associated with either of two common Caribbean anemones, *Bartholomea annulata* (Lesueur) and *Condylactis gigantea* (Weinland), either resting on the anemones or occupying the

FIGURE 2. *Periclimenes* (*Periclimenes*) *yucatanicus* (Ives).

same crevice. As many as six of these shrimps may be found on a single anemone. The anemones are usually, but not always, attached to hard substrate buried in fine sand or mud at depths ranging from just below low tide line to at least 23 meters (Holthuis, 1951).

In the presence of fishes, and sometimes just in the presence of the observer, these shrimps may lash their antennae together and sway back and forth. On two separate occasions they were observed with juvenile fishes, including three-spot goatfishes *Upeneus maculatus* (Bloch); filefishes (Monacanthidae); and yellowtail snappers, *Ocyurus chrysurus* (Bloch). The contacts between fish and shrimp were momentary, and the shrimp did not leave the substrate.

These shrimps may possibly be examples of clever mimicry and not cleaners. The senior author has observed fishes that mimic cleaner fishes only to take bites out of would-be hosts. The victims were invariably juvenile fishes.

Periclimenes (Periclimenes) pedersoni Chace, 1958
Figures 3-4

The Pederson cleaning shrimp is another small species with a maximum body length of not more than four centimeters. The antennal flagella are longer than the body and, with the antennular flagella, seem to form a protective cage over the body. The shrimp is smooth. It is sexually dimorphic, especially in the form of the rostrum; females and young males closely resemble *P. yucatanicus* except for the color pattern.

The body is transparent with longitudinal white lines running posteriorly from the bases of the third maxillipeds and converging dorsally near the posterior margin of the third abdominal somite. Between the white lines on the dorsal surface of the abdomen are a variable number of violet spots of irregular sizes. Outside of the white lines on either side of the posterior half of the third abdominal somite are two or three similar small spots of violet followed by a large, triangular, violet patch bordered with white. There are usually two violet spots in the dorsal midline of each of the fourth and fifth somites, a few smaller lateral spots on those somites, and four or five spots in a longitudinal row on each side of the sixth somite. There may or may not be a white stripe in the dorsal midline of the sixth somite, as well as near the posterior margins of the two preceding somites. The telson bears two or three violet spots in the midline and a trans-

verse bar of the same color proximad to the white tip. An opaque white line marks the ventral midline of the body from the posterior part of the thorax to the middle of the sixth abdominal somite. The eyes are opaque pink. The eyestalks are transparent with a purple and, sometimes, a white line below. The outer antennular flagella are entirely white; the inner ones are transparent. The antennal flagella are mostly opaque white, but transparent at their bases. The third maxillipeds are opaque white at the base and tip, banded with violet elsewhere. The smaller chelipeds are banded with purple, and the fingers are tipped with brown. The larger chelipeds are banded with purple on the distal half of the fingers, distal half of the palm, and distal part of the carpus or proximal part of the palm; there are brown saddles on the inner surface near the base of the palm and on the carpus, and purple saddles on the inner surfaces of the ischium and merus. The walking legs are translucent. The uropods are tipped with

FIGURE 3. *Periclimenes* (*Periclimenes*) *pedersoni* Chace. (Modified from Chace, 1958.)

blue violet, outlined proximally and laterally with white, and there are a few violet spots near the bases of the uropods. Although the general color pattern of this species is constant and characteristic, the details of the pattern are subject to considerable variation. Specimens collected off the west coast of Florida that agree morphologically with *P. pedersoni*, although they were not associated with sea anemones and were not observed cleaning fishes, have fewer and redder spots on the abdominal somites and telson, reddish markings on the antennular peduncles and basal parts of the inner antennular flagella, a pair of red bands on the otherwise white antennal flagella, yellow bands on the chelipeds, and blue, violet, red and yellow bands on the walking legs, especially the posterior pair.

We have taken this species in the Bahamas and the Virgin Islands. It has also been collected at Antigua, British West Indies, and the color variety described above is reported to be common in 17 meters of water off West Florida.

In general, these shrimps seem to be found in areas protected from violent surge. In all cases, except off West Florida, they have been observed associated with the anemone, *Bartholomea annulata* (Lesueur), usually hanging directly to the anemone or occupying the same hole. We have observed them at depths ranging from 1.5 to 9 meters in the Bahamas and Virgin Islands. The species frequently occurs in pairs, but it is often solitary or, in rare cases, it is found in groups of up to five. The individuals may remain from one to three weeks on the same anemone and possibly even longer. They may on occasion completely disappear, however, or show up on a new anemone a short distance away.

The Pederson shrimp attracts the attention of a great variety of reef fishes by whipping its antennae and by swaying back and forth from a prominent position on or near the anemone. Fishes often line up or crowd around waiting their turn to be cleaned. When we removed the shrimp, fishes continued to visit the same anemone for over a week. Fishes cleaned include: three-spot goatfish, *Upeneus maculatus* (Bloch); squirrel fishes, *Holocentrus,* spp.; yellow grunt, *Haemulon flavolineatum* (Desmarest); Nassau grouper, *Epinephelus striatus* (Bloch); rock hind, *Epinephelus adscensionis* (Osbeck); parrot fish, *Sparisoma viride* (Bonnaterre); yellow-backed porgy. *Calamus calamus* (Valenciennes); filefishes, Monacanthidae; queen triggerfish, *Balistes vetula* Linnaeus; and peacock flounder, *Bothus*

FIGURE 4. *Periclimenes pedersoni* cleaning a squirrelfish, *Holocentrus*, sp. (Photograph courtesy of Walt Disney Productions.)

lunatus (Linnaeus). The shrimp boards the fish as soon as the latter comes close enough and quiets down. It swims head first or crawls to the fish. Parasites are removed as the shrimp moves rapidly over the fish. In this operation, it pulls directly at the parasite or opens the tissue surrounding it. If the shrimp encounters a wound, it will spend considerable time picking at the injured flesh. As the shrimp approaches the gill region, the fish opens the gill cover and allows the shrimp to enter. The action is repeated on the opposite side. The shrimp is also allowed to enter, and leave, the mouth. If the observer gets too close to a large fish, the shrimp either swims out or is ejected from the fish's mouth before the fish retreats. It is suspected that this shrimp includes, as part of its diet, undesirable food particles taken from the gills and teeth of the fish. When the shrimp is apparently satiated, it retires to the anemone, often with many fishes still waiting to be cleaned. At some cleaning stations, the shrimps' activities are joined by the cleaning fish, *Elacatinus*, sp.

The sea anemone, *Bartholomea annulata,* with which *P. pedersoni* is associated has several other interesting companions. Clarke (1955) described the red mysid, *Heteromysis actiniae,* which commonly swims among its tentacles. He also mentioned the snapping shrimp, *Alpheus armatus* Rathbun, which lives in pairs with the anemone. This snapping shrimp is apparently dependent upon the anemone for protection and vice versa. The snapping shrimp digs a burrow for both of them. It spends most of its time at the burrow entrance with its banded antennae mixed with the banded tentacles of the anemone. If danger comes near, the shrimp withdraws quickly, causing the anemone to contract and plug the entrance of the burrow. The shrimp was often observed to chase small blue damsel fishes, *Pomacentrus,* with its trigger claw. The snapping shrimp was invariably associated with the anemone off New Providence Island, Bahamas, but William Clarke (personal communication) maintains that this was not the case off Bimini. In a simple experiment, we removed the snapping

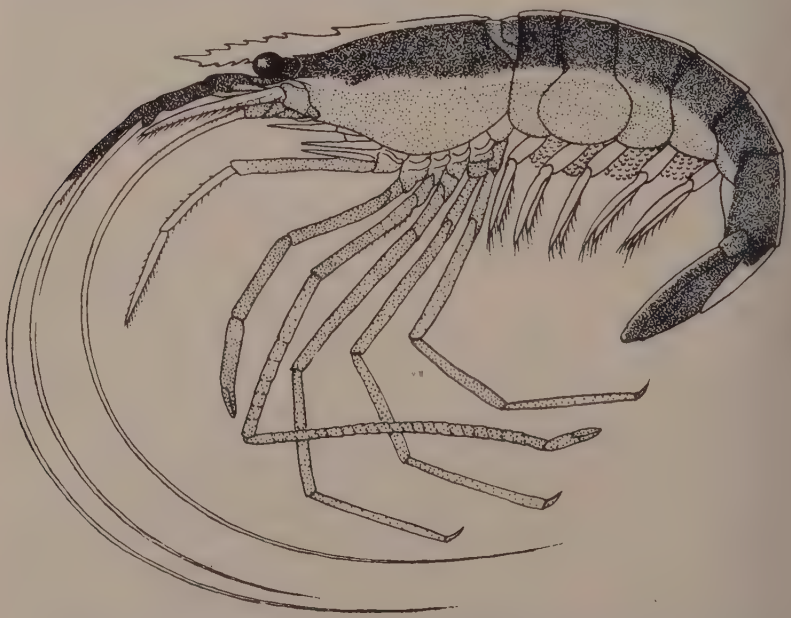

FIGURE 5. *Hippolysmata* (*Hippolysmata*) *grabhami* Gordon. (Modified from Gordon, 1935.)

shrimps from one anemone. Within a few days, only pieces of the anemone could be located, and they had obviously been preyed upon; subjective suspicion points to the stomatopods which are abundant in the same area. These same snapping shrimps in an aquarium seek out the anemones very quickly. In addition to this shrimp, there are other associates of this anemone which should be briefly mentioned: juvenile arrow crabs, *Stenorynchus seticornis* (Herbst); various small hermit crabs; a finspot fish, *Paraclinus grandicomis* (Rosén); and a cardinal fish, Apogonidae.

Family Hippolytidae

Hippolysmata (Hippolysmata) grabhami Gordon, 1935

Figures 5-6

The red-backed cleaner shrimp is intermediate in size. The body lengths of those observed were estimated to be five centimeters or less, but the species is known to reach a length of at least 68 mm (Gordon, 1935). The antennae are longer than the body. The body and appendages are smooth.

The color is yellow ochre with a broad, red, longitudinal band extending from the basal part of the outer antennular flagella, along the carapace and abdomen, to the uropods. The red band is bisected for its entire length in the dorsal midline by an opaque white stripe. Most of the outer antennular flagella, the inner antennular flagella, the antennal flagella, the two distal segments of the third maxillipeds, and most of the telson are also white. The eyes are brown. The coloration of this shrimp seems to be very constant. The white of the antennae, tail, and back are conspicuous in the crevices in which the shrimps are found, but the antennae were not observed being displayed in the sunlight. It may be more than coincidental that the color pattern of this shrimp, although not necessarily the actual colors, is very similar to the patterns of at least three of the cleaner fishes: *Labroides dimidiatus* (Cuvier and Valenciennes), *Aspidontus taeniatus* Quoy and Gaimard, and *Elacatinus oceanops* Jordan.

H. grabhami has been recorded from Madeira (Gordon, 1935) and the Society Islands (Randall, 1958). It has also been found off southeastern Florida and in the Hawaiian Islands. Two pairs were observed off New Providence Island, Bahamas: one pair at Lyford Bay at a depth of two meters; the other off Hog Island under a small coral head at a depth of three meters.

FIGURE 6. *Hippolysmata grabhami* cleaning a moray, *Gymnothorax*, sp., in Florida. Nearly hidden in the right foreground is a *Stenopus hispidus*. (Photograph by E. L. Fisher, Marine Laboratory, University of Miami.)

Those seen in the Bahamas were in large, shaded coral crevices on small, isolated coral heads in protected waters. Those crevices were occupied by unusually large numbers of fishes. In the more open and larger crevice off Hog Island, a pair of *Stenopus hispidus* shared a different area of the same crevice; it is interesting that the specimen photographed off Florida (Figure 6) was also accompanied by *S. hispidus*. Like the two species of *Stenopus, H. grabhami* does not seem to wander but restricts its movements to a certain small area of a crevice. The pair at Lyford Bay was observed in the same part of the same crevice from April through August, 1956. The individuals of a pair attempt to stay together. They lived on the walls of the crevice at Lyford Bay, on the roof of the crevice off Hog Island, and were observed by Randall (1958) in the open on coral blocks at a depth of 21 meters in the Society Islands.

In the Bahamas, they lashed their antennae vigorously in the presence of fishes and sometimes at the observer. Unfortunately the configuration of the crevices made it difficult to observe the cleaning activities of these shrimps; on one occasion a blue tang, *Acanthurus*

caeruleus Bloch and Schneider, was observed being cleaned. The crevice at Lyford was invariably crowded with medium-sized fishes. In particular, they crowded around the shrimps which reached from the substrate and picked at the various fishes. Randall (1958) records the cleaning activities of this species in the Pacific. He identified the following fishes as having "entered into a symbiotic association" with the shrimp: *Apogon exostigma* (Jordan and Stark); *Apogon,* sp.; *Anthias,* sp.; juvenile *Acanthurus mata* (Cuvier), and *Gymnothorax flavomarginata* (Rüppell). He noted that the shrimp climbed onto the head of the latter moray.

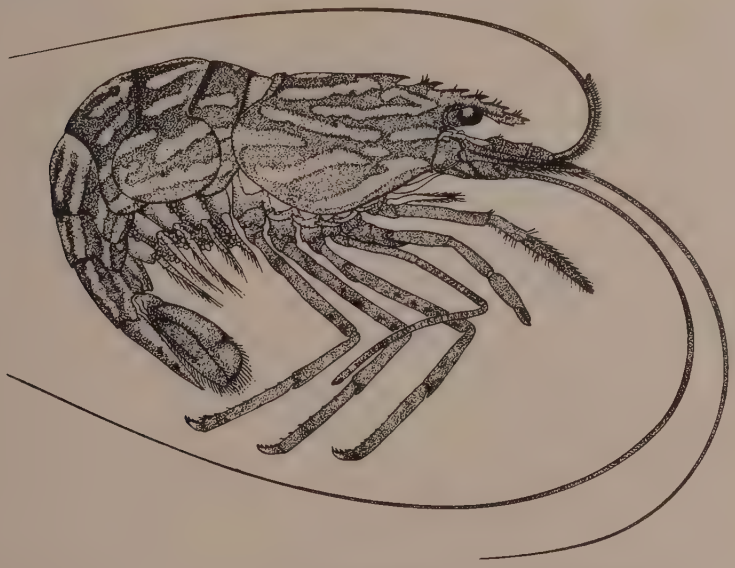

FIGURE 7. *Hippolysmata* (*Hippolysmata*) *californica* Stimpson.

Hippolysmata (Hippolysmata) californica Stimpson, 1866
Figure 7

Hippolysmata californica is one of the larger and heavier-bodied cleaning shrimps. The body may attain a length of up to seven centimeters or slightly more in the northern part of its distribution. The antennae are longer than the body but, because they are red, they are not as conspicuous as those of the other cleaning shrimps.

The body and legs are smooth.

The color is translucent red, striped with rows of pink. The eyes are brown but the stalks have a white line down the front or lower surfaces which continues onto the body and converges to form a Y on the ventral side of the shrimp. In their own environment under natural light conditions, they are not conspicuous except for the white Y which is seen when the shrimp faces the observer. At night when these shrimps are most active, their eyes reflect artificial light as orange.

They have been reported from Santa Barbara, California, to Ensenada, Baja California (Ricketts and Calvin, 1952). Observations of the senior author confirm this distribution and extend it south to Sebastion Viscaino Bay and Guadalupe Island.

These shrimps are found in protected, rocky crevices and human artifacts from the back bays to the open coast and from tide pools to depths of at least 61 meters. They are highly gregarious and sometimes are found in groups of several hundred. They wander at night, but retire to cover during the day. The individuals quarrel a great deal with one another, particularly about food.

The three heavily integumented forms that are known to be cleaned by this shrimp under natural conditions are all part of the Southern California fauna, with distributions similar to that of the shrimp. They include the California moray, *Gymnothorax mordax* (Ayres); the garibaldi, *Hypsypops rubicunda* (Girard); and the California spiny lobster, *Panulirus interruptus* (Randall). These shrimps continually feed on the epibiose of the rocky substrate on which they occur, and they are probably not greatly dependent upon cleaning for food. They do not seem to try to attract fishes, but simply occupy holes where certain fishes and lobsters are found. When a suitable fish or lobster enters a crevice occupied by these shrimps, the latter will crawl or swim to the invader and clamber rapidly over the entire outside surface of the animal, stopping and picking at favorable areas. A diver's hand will receive the same attention, particularly the finger nails. The fishes do not seem to be bothered, although the moray may occasionally jerk its head as if annoyed. In some cases the shrimps may enter the mouths of these eels, but apparently not without some risk, for the stomachs of California morays examined at Guadalupe Island yielded a considerable number of these shrimps. On the other hand, in an aquarium where a fish cannot escape, the shrimps will clean it to the bone.

Hippolysmata californica therefore exhibits a rather simple and imperfect relationship with its hosts, sometimes eating them and sometimes being eaten itself. During the cleaning process, the shrimps seem only to seek food on a new substrate. From this simple and hazardous relationship, it is easy to visualize an evolutionary path by which the more complex cleaning behavior could have developed. We do not mean to imply that *H. californica* or its close relatives were the first cleaner shrimps. We merely offer its behavior as a model of how cleaning may have begun.

Family Stenopodidae

Stenopus hispidus (Olivier, 1811)

Figure 8

This species is the largest of the known cleaner shrimps. The body may attain a length of more than seven and a half centimeters. The

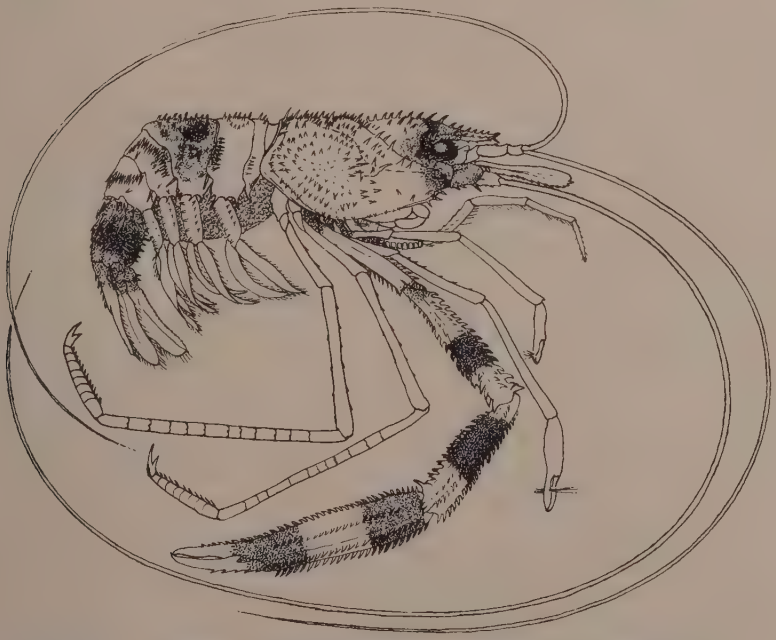

Figure 8. *Stenopus hispidus* (Olivier). (Modified from Bate, 1888.)

antennae and antennules are considerably longer than the body. The body and larger chelipeds are spiny.

The striking color of this shrimp has attracted considerable attention (Roughly, 1936, and Utinomi, 1956) and some speculation (Herrick, 1893). The body and legs are white with bands of red. A blotch of red is located on the anterior part of the carapace. The bases of the legs of large adults are blue. The antennae and antennules are white. The eyes are brown, and the large cluster of eggs carried by the female are turquoise. The color brilliance usually contrasts sharply with the generally dull background of gray coral rock. In the shaded environment, the red is dulled, but the white remains conspicuous. The antennae, which are usually displayed in the sunlight, are clearly visible.

Stenopus hispidus occurs throughout the Indo-Pacific region from the Red Sea and South Africa to the Hawaiian and Tuamotu Islands; in the western Atlantic, it is found from Bermuda and southern Florida to the north coast of South America (Holthuis, 1946). It is not known from the eastern Pacific or eastern Atlantic. The senior author was unable to find it during expeditions along the coast of Mexico and around Clipperton Island but, in the Atlantic, we found it to be common off the Bahamas, Puerto Rico and Virgin Islands.

Pairs were observed in quiet, shallow water where fishes were abundant. The pairs were most commonly located in shaded coral crevices or caves, usually on the ceiling near the entrance where the antennae could be displayed in the sunlight. Occasionally they were found in large holes or undercut mats of rhizomes of the turtle grass, *Thalassia*. Frequently they occupied discarded man-made objects such as auto tires, buckets and the like. In less protected areas, such as the seaward sides of islands, they do not commonly inhabit the very shallow, turbulent water. They usually occur at depths of two to four meters. A few, however, have been observed just below the low tide line in areas where the water is very calm, and the species has been recorded from a depth of 210 meters (Holthuis, 1946). Juveniles appear to pair and grow up together. Adults, as well as juveniles, were never observed to move more than half a meter except when disturbed by the investigator. They probably remain in an area of less than a square meter many months, possibly years. The pairs attempt to stay together even when disturbed.

The caves occupied by *S. hispidus* are frequented by a large

variety of reef fishes, particularly morays, tangs, grunts and groupers. Unfortunately, the presence of a diver at the entrance of their retreat disturbs the cleaning activity and makes observations almost impossible. One of the authors (Pederson) observed one of these shrimps cleaning a white-spotted moray. The shrimp approached the moray, placed its large chelipeds around the eel, and proceeded to clean with its smaller claws. The shrimp was not observed to leave the substrate but only reached out to clean. On another occasion, the senior author observed a juvenile shrimp of this species picking at the side of a blue tang, *Acanthurus caeruleus* Bloch and Schneider. The tang was resting near the base of a coral boulder in which there was a small crevice into which the fish partially curved its body. All that could be seen of the small shrimp was its large chelae which were against the fish, its antennae, and the small claws which were presumably picking parasites. The fish finally became alarmed at the presence of the observer and swam away. In many instances, fishes in awkward positions were observed beside these shrimps, but they were disturbed by the presence of the observer before any cleaning activity ensued. There is no doubt, however, that these fishes were being cleaned.

No natural predators of this shrimp were found by us. In a simple experiment, an octopus was caged with a pair of these shrimps. The shrimps were not eaten until the octopus had gone without food for several weeks; usually octopuses will feed readily on crustaceans on the second or third day of captivity. Possibly the octopus had difficulty catching the shrimps, which are quite agile. That *S. hispidus* is not entirely immune from predators is indicated by Randall and Brock (1960) who found two complete specimens of this shrimp in the stomach of a grouper, *Epinephalus merra* Bloch, and a chela in the stomach of another grouper, *Cephalopholis miniatus* (Forskal).

The wide distribution, plus the background life-history work that has been done on this shrimp (Herrick, 1893), suggest that it would be an excellent subject for further research.

Stenopus scutellatus Rankin, 1898
Figure 9

This species is smaller than *S. hispidus* but similarly proportioned. It attains a body length of about three and a half centimeters. The

antennae and antennules are considerably longer than the body. The body and larger claws are spiny.

The general color pattern and structure of this species are similar to those of *S. hispidus*, but the back is lemon yellow. The yellow may be an advantage in advertising the presence of this shrimp, which lives in smaller and usually darker crevices than those occupied by *S. hispidus*.

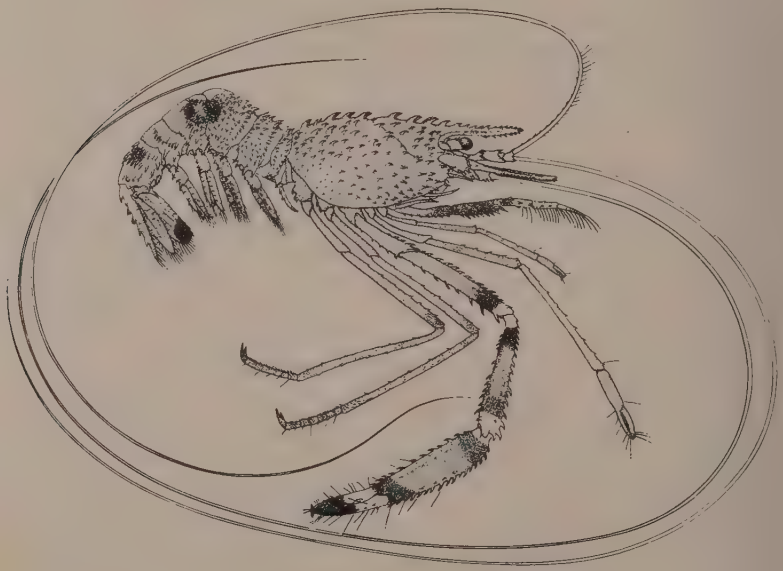

FIGURE 9. *Stenopus scutellatus* Rankin.

The recorded distribution of *S. scutellatus* is from Bermuda to Fernando de Noronha, Brazil, from shallow water to 55 meters. (Holthuis, 1946). We have found it to be common off New Providence Island in the Bahamas in depths ranging from just below low tide to six meters or more. All were observed on isolated solid substrates in or near large beds of turtle grass (*Thalassia*) in protected, quiet waters. They always occurred in pairs, often in discarded human artifacts, and commonly in coral boulders.

It is believed that they remain within centimeters of the same spot. One pair was observed in the same football-sized coral boulder

from May through August 1956. During that period, we changed the position and orientation of the boulder several times within a radius of approximately seven meters without disturbing the shrimps. Visiting fishes were momentarily disturbed by the changes, but they soon relocated the shrimps.

These shrimps also whip their antennae in the sun in front of the dark hole in which they live in order to attract fishes. To clean a fish thus signaled, they simply reach out of their hole and pick at their host. On rare occasions, they were observed to leave their holes to clean, but they never climbed onto the fish. The most common visitors to these shrimps were the three-spot goatfish, *Upeneus maculatus* (Bloch), and the yellowtail snapper, *Ocyurus chrysurus* (Bloch). In addition to the visitors, the crevices inhabited by these shrimps often housed unusually large numbers of small fishes, such as apogonids. The goatfishes often placed their barbels inside the hole in order to have them worked on.

The two species of *Stenopus* that inhabit the same general area in the Bahamas have somewhat similar markings and habits. They do, however, have significant differences, particularly in their habits and habitats. *S. hispidus* prefers large, open crevices or caves and cleans larger fishes, while *S. scutellatus* prefers small holes or crevices and cleans only small fishes.

Discussion

Among the various degrees of specific interdependence demonstrated by these few cleaning shrimp examples, we can see some interesting patterns in several fields of biology. The bright markings that advertise the presence of these shrimps suggests a new significance for color in the marine environment. The interesting similarities in morphology and behavior suggest convergent evolution. The behavior itself, with its complex interaction between cleaners and hosts, provides an area for study by behaviorists. The wide distribution of two species of cleaners is subject matter for the zoogeographer to explore in more detail. The parasitologist should find answers to some of his questions, such as a reasonable explanation for parasites to blend well with their background on the host and an explanation of the natural control of some fish diseases. The implications for the economic biologist involved in fisheries work are obvious. The importance of these shrimps in controlling the external parasites of

the associated reef fishes must be considerable. They must, then, be responsible for higher fish populations, and consequently exert a profound influence on the ecology of the nearby areas.

Acknowledgments

Rarely have so many contributed so much to a study of this scope. We wish to express our gratitude to all of those mentioned below who responded most unselfishly to our requests for specimens, photographs, observations, identifications, or perusal of manuscript drafts: Cadet Hand of the University of California, Berkeley; W. J. North and James Stewart of the Institute of Marine Resources, University of California, La Jolla; William D. Clarke, Gifford Ewing, Raymond Ghelardi, Carl L. Hubbs and Nan Limbaugh of the Scripps Institution of Oceanography, University of California, La Jolla; R. B. Cowles of the University of California, Los Angeles; Demorest Davenport of the University of California, Santa Barbara; William H. Amos of the University of Delaware; Erwin Verity of the Disney Studios; Bonnie Eldred and Robert F. Hutton of the Florida State Board of Conservation Marine Laboratory, St. Petersburg; L. B. Holthuis of the Rijksmuseum van Natuurlijke Historie, Leiden, The Netherlands; E. L. Fisher, Raymond B. Manning, Anthony J. Provenzano, Jr., John E. Randall and Gilbert L. Voss of the University of Miami Marine Laboratory; James E. Böhlke and Charles C. G. Chaplin of the Academy of Natural Sciences of Philadelphia; Ron Church and Bev Morgan of Scientific Diving Consultants; Frederick M. Bayer, Thomas E. Bowman, Charles E. Cutress, Ernest A. Lachner and Waldo L. Schmitt of the U. S. National Museum, Smithsonian Institution; Dr. Richard Kirk of Madeira Beach, Florida; Desmond V. Nicholson of St. Johns, Antigua, British West Indies, and Verne Pederson of La Jolla, California.

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THE GROWTH, BREEDING CYCLE AND FOOD OF THE FLYINGFISH *PAREXOCOETUS BRACHYPTERUS HILLIANUS* (GOSSE)

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Abstract

Parexocoetus brachypterus hillianus (Gosse) occurs commonly in the coastal waters of Barbados, W.I. It is a fast growing species which reaches maturity in one year. Breeding takes place from September to the end of December. It is a plankton feeder.

Introduction

Parexocoetus brachypterus hillianus (Gosse) is one of the commonest species of flyingfishes occurring in the waters in the vicinity of Barbados, W.I. It occurs locally in large shoals and is the only species which is found in considerable numbers within a few hundred meters of the shore. It is a small species reaching a length of 12 to 13 cms at maturity. The large, darkly pigmented dorsal fin makes it readily identifiable in flight. An account of the distribution and a description of the adults has been published by Bruun (1935).

Material was obtained from dip-net collections made at night off the west coast of Barbados. Large numbers of this and other species of flying fish were attracted by a 220 volt underwater light suspended just below the surface. As many as several hundred specimens were taken on nights with no moon in the space of an hour or two (Lewis, 1959).

I am indebted to Dr. Anton F. Bruun of the Zoological Museum, Copenhagen, for his identification of the species.

Growth

Size frequency histograms of catches for 1959 and 1960 are shown in Fig. 1 (a) and (b). Juvenile stages 3 to 5 cms in length were taken in March of 1959. No specimens were collected in April, but in May juveniles in the 4 to 6 cm range were captured. In June the largest numbers of juveniles were in the 6 to 7 cm range and during the same month considerable numbers of adults 11 to 12 cms long were also collected. The histogram for June thus shows two peaks, the juveniles in the 6 to 7 cm range and the fully grown adults. Dur-

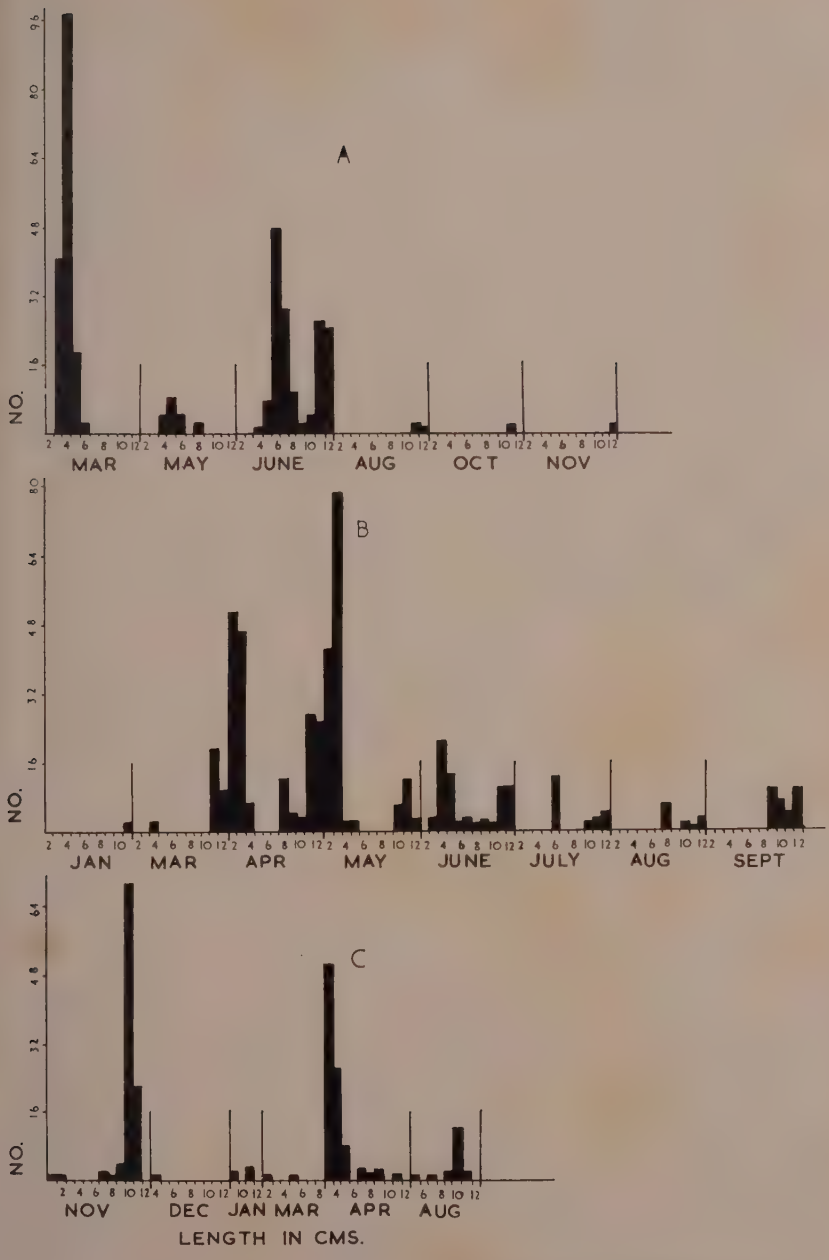

FIGURE 1. Length frequency histograms. A-1959. B-1960. C-from Bruun (1935).

ing the balance of the year only small numbers of adults of 11 to 12 cms were taken.

In 1960 the juveniles first appeared in April when large catches of specimens in the 2 to 3 cm range were made. The histogram during this month is bimodal, for, in addition to the juveniles, there were large catches of adults in the 11 to 12 cm range. A slight increase in the size of the juveniles is reflected in the data for May. During this month the greatest numbers occurred in the 3 cm range. In June the greatest number of juveniles taken were in the 4 to 5 cm range, and in July in the 6 cm range. In August and September, juveniles reached a length of 8 to 10 cms and a few adults were taken during the same two months.

Further information on the growth rate of the species is contained in Bruun's report (1935) and his data are shown in Fig. 1c. Juveniles in the 3 to 5 cm range were taken in April in considerable numbers. A trace of young stages appeared previously from November to March. No very young individuals were taken in August when the collection was composed of specimens ranging between 6 and 12 cms. The November collection consisted predominantly of adult specimens.

From the Barbados collection and from Bruun's data, it appears that *P. brachypterus* is a fast growing species which reaches full size in one year. The bimodal nature of the histograms indicates a population composed of juveniles of the same spawning group together with fully grown adults. Juveniles of 2 to 4 cms appear in the spring

TABLE 1

PERCENTAGE OF ADULT INDIVIDUALS WITH DEVELOPING GONADS

	Month	Total	Per cent with Ripening Gonads	Per cent Ripe
1959	June	50	0	0
	Aug.	3	0	66
	Oct.	2	100	0
	Nov.	2	0	100
1960	Jan.	1	0	0
	March	28	0	0
	April	52	0	2
	May	21	0	0
	June	20	4	0
	July	9	30	0
	Aug.	6	20	10
	Sept.	18	30	20

in March and April, reach a length of 6 to 7 cms by the end of June and likely attain full size about November.

Breeding Cycle

While only small numbers of ripe or nearly ripe individuals were collected, the seasonal occurrence of these specimens does give an indication of the breeding cycle of the species. In 1959 nearly ripe (gonads rounded, eggs fully visible) females were taken in August and October, and ripe individuals were taken in November. In 1960 individuals with ripening gonads were taken in July. In August all specimens had nearly ripe gonads, and in September the collection was composed of individuals with nearly ripe or ripe organs. Table 1 shows the percentage of ripe and nearly ripe individuals taken each month.

A restricted breeding season is thus indicated for this species. Gonad development begins in July and August and, since no ripe individual was found after the end of December, breeding apparently takes place between September and January. That juveniles first make their appearance in March and April strengthens this conclusion.

Food

The stomach contents of 30 specimens of various sizes collected at different times of the year were examined. The analysis of the contents is shown in Table 2.

P. brachypterus appears to be predominantly a plankton feeder. In stomachs which contained partly undigested food, nearly all contained the skeletons of copepods. The commonest species noted were *Undinula vulgaris, Candacia pachydactyla* and *Corycaeus obtusus*. The remains of small fishes, scales and bones were found in only a few individuals. Skeleton remains of decapods and other Crustacea were common but were never abundant in any stomachs.

Juveniles

A large collection of juvenile specimens from 2 cms in length upwards has made it possible to identify all the young stages of the species. Three juvenile stages of 23, 48 and 67 mm are shown in Fig. 2, together with an adult specimen.

The young stages are similar in general appearance and coloration to the adult. The long, heavily pigmented dorsal fin is characteristic

TABLE 2

Analysis of Stomach Contents

Date	S.L. in mms	Contents
18.1.58	122	White well digested paste. One isopod and few fish scales.
5.6.59	75	White granular paste, nothing recognizable.
"	65	White granular paste, pink paste mixed with the skeletons of 50-100 copepods (chiefly *Coryeaeus obtusus*).
"	72	White granular paste, nothing recognizable.
"	62	Pink paste, few copepod skeletons, 3 Siphonophores.
"	66	White paste only, nothing recognizable.
"	57	White paste only, nothing recognizable.
17.9.59	121	Remains of a small myctophid fish.
"	120	White paste only, nothing recognizable.
28.9.59	117	White paste, leg of a decapod crustacean.
"	122	Pink paste, remains of calanoid copepod skeletons.
18.1.60	121	White paste only, nothing recognizable.
28.3.60	108	Small amount of well digested white paste.
"	96	Stomach nearly empty.
"	102	Stomach empty.
4.4.60	112	Small amount of well digested pink paste and copepod skeletons.
"	120	Pink paste and skeletons of 50-100 *Candacia pachydactyla, Corycaeus obtusus* and *Undinula vulgaria.*
"	125	Pink paste and copepod skeletons.
24.5.60	76	White paste only, nothing recognizable.
"	85	White paste, copepod skeletons.
24.5.60	80	White paste only, nothing recognizable.
"	82	Pink paste, copepod skeletons.
"	95	Stomach nearly empty.
30.5.60	110	Stomach filled with reddish paste and skeletons of *Undinula vulgaris.*
"	85	Stomach filled with reddish paste and skeletons of *Undinula vulgaris.*
16.6.60	115	*Candacia pachydactyla,* about 100; *Undinula vulgaris,* about 50; small fish ribs.
"	122	Contains well digested reddish paste, 25-30 skeletons of *Candacia pachydactyla*; several small pieces of fish muscle and ribs of small fish.
18.7.60	121	*Undinula vulgaris,* 200-300 skeletons; scales and bones of a small fish; about 25 *Candacia pachydactyla* and a red gritty material.
"	112	*Undinula vulgaris,* 25-50; *Candacia pachydactyla,* 10; 6 mollusc opercula and red gritty material.

of all stages. Stages up to 80 or 85 mm are, however, also characterized by the presence of a pair of long barbels attached to the lower jaw. Fully grown adults lack the barbels.

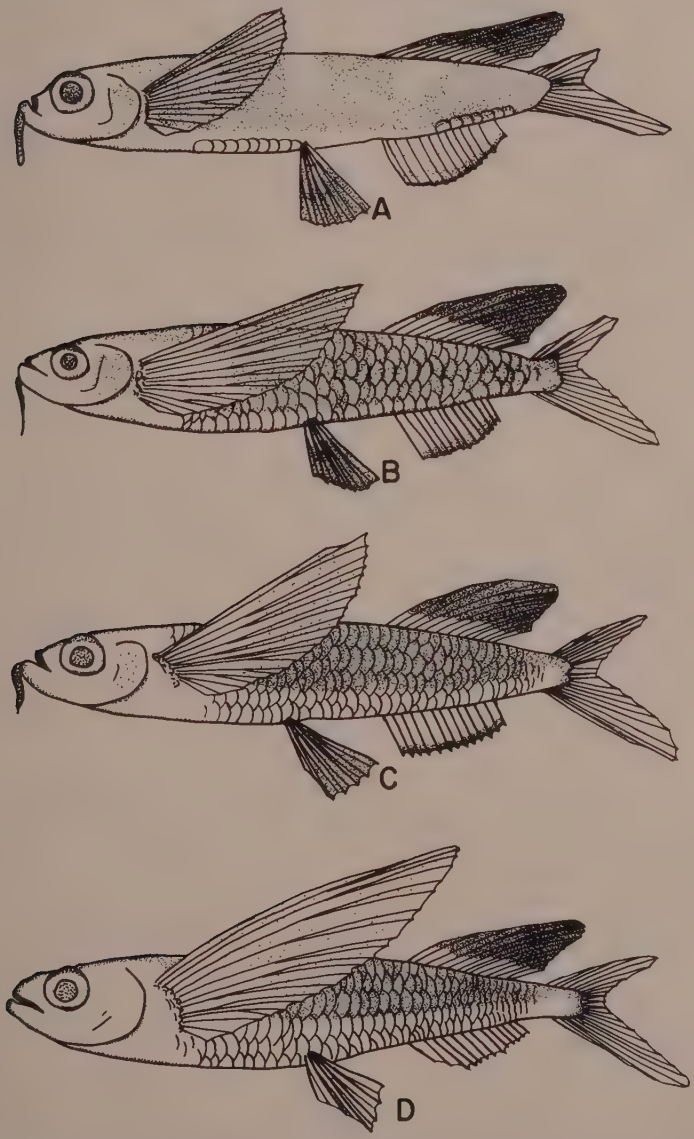

FIGURE 2. Juveniles and adult. A-23 mm. B-48 mm. C-67 mm. D-Adult.

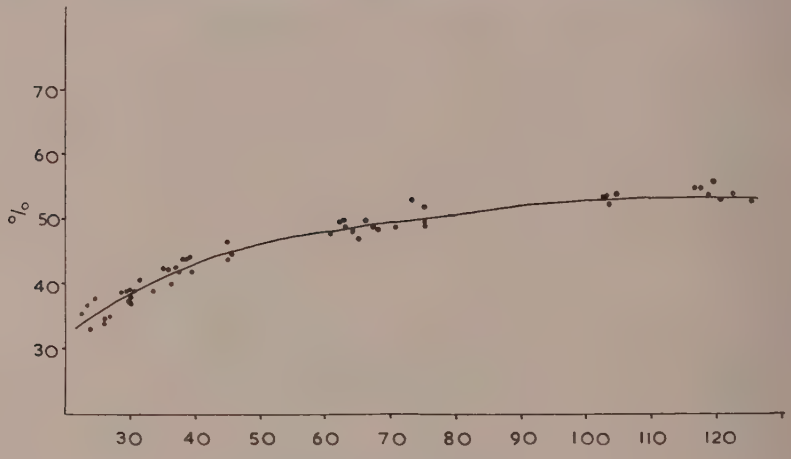

FIGURE 3. Relative length of pectoral fin in juveniles.

In the 23 mm stage the body is lightly pigmented with two dorsal areas which are lighter than the rest of the body. The pelvic and pectoral fins are both dusky and the edge of the anal fin is pigmented as well. The lower jaw is turned upwards so that the mouth lies above. The barbels are long and stout. The pectoral fin is about 35 per cent of the standard length (Fig. 3).

TABLE 3

COUNTS AND MEASUREMENTS (IN PER CENT OF STANDARD LENGTH) OF JUVENILES OF *P. brachypterus hillianus* IN THE 3.0-3.5 CM RANGE

Standard Length	3.1	3.3	3.1	3.0	3.3	3.4	3.5	3.1	3.2	3.3
Dorsal Rays	12	12	12	12	12	12	12	12	13	12
Anal Rays	13	13	13	13	13	13	13	13	13	13
Pectoral Rays	13	13	14	13	13	13	14	13	13	13
Predorsal Length	71	70	69	72	70	69	70	70	70	69
Preventral Length	39	52	54	37	52	51	52	52	53	54
Preanal Length	69	70	70	70	70	70	69	70	70	69
Length of Head	24	24	22	23	23	22	23	24	24	23
Diameter of Eye	8	8	8	8	8	8	8	7	8	8
Interorbital Height	12	12	13	14	13	13	14	12	13	14
Length of Pectoral	40	41	39	40	40	39	40	41	39	40
Length of Ventral	19	21	21	20	21	19	20	21	20	21
Height of Body	18	17	18	17	17	17	18	18	17	18
Length of Barbel	10	11	13	10	10	10	9	10	11	13

TABLE 4

COUNTS AND MEASUREMENTS (IN PER CENT OF STANDARD LENGTH) OF JUVENILES OF *P. brachypterus hillianus* IN THE 4.0-5.0 CM RANGE

Standard Length	4.7	4.3	4.5	4.5	4.3	4.3	4.5	3.8	5.1	3.9
Dorsal Rays	12	12	12	12	12	12	12	12	12	12
Anal Rays	13	13	13	14	13	13	13	13	13	13
Pectoral Rays	13	13	14	13	13	13	14	13	14	14
Predorsal Length	70	68	69	68	69	69	70	70	69	69
Preventral Length	53	52	52	51	53	51	52	55	52	53
Preanal Length	69	69	70	68	71	70	70	70	69	70
Length of Head	25	24	26	24	26	25	24	24	23	23
Diameter of Eye	8	8	8	8	8	8	8	10	8	9
Interorbital Breadth	14	13	12	12	12	13	13	12	13	12
Length of Pectoral	47	45	44	49	45	45	49	46	46	47
Length of Ventral	20	21	22	22	22	20	22	22	21	22
Height of Body	18	18	17	17	17	17	19	18	17	18
Length of Barbel	8	9	10	15	10	10	10	11	12	10

In the 48 mm stage, only the distal half of the pectoral fin is pigmented. The scales are completely formed and the pectoral fins are about 47 per cent of the standard length. In the 67 mm stage, the pectoral fins are about 50 per cent of the standard length and are only faintly dusky. The distal halves of the pelvic fins are pigmented. In the adult stages the pectorals are only faintly pigmented and the pelvic and anal fins are clear.

The juvenile stages described from the Barbados material are in agreement with the juveniles described by Breder (1938). Measure-

TABLE 5

COUNTS AND MEASUREMENTS (IN PER CENT OF STANDARD LENGTH) OF JUVENILES OF *P. brachypterus hillianus* IN THE 5.5-7.5 CM RANGE

Standard Length	7.0	6.3	6.5	6.9	5.7	7.4	6.3	7.4	7.1	6.6
Dorsal Rays	11	13	12	13	12	12	11	12	12	12
Anal Rays	13	14	13	13	13	13	12	13	14	13
Pectoral Rays	13	13	14	13	13	13	13	13	14	14
Predorsal Length	68	70	70	70	70	70	71	70	69	70
Preventral Length	58	52	54	54	52	53	54	53	55	53
Preanal Length	69	70	70	70	70	70	70	69	69	69
Length of Head	23	25	26	23	24	24	26	24	24	24
Diameter of Eye	8	8	8	7	8	7	8	7	7	8
Interorbital Breadth	13	14	13	13	14	13	13	13	15	13
Length of Pectoral	50	48	49	47	47	50	46	49	46	50
Length of Ventral	20	21	21	19	19	19	19	19	18	19
Height of Body	18	18	16	17	18	19	17	18	17	17
Length of Barbel	9	8	8	7	9	8	5	7	7	7

ments of 3 juvenile size groups and of adults are contained in Tables 3 to 6, inclusive. These agree closely with the measurements of Breder (1938) for this species, but indicate a slightly wider variation in dorsal- and anal-ray counts than does Breder's material.

TABLE 6

COUNTS AND MEASUREMENTS (IN PER CENT OF STANDARD LENGTH) OF ADULTS OF *P. brachypterus hillianus*

Standard Length (cm)	11.4	11.8	11.7	11.0	12.1	12.7	12.1	12.1	12.0	12.5
Dorsal Rays	12	12	12	12	12	13	12	12	12	12
Anal Rays	13	13	13	13	13	12	13	13	12	13
Pectoral Rays	13	13	13	13	13	13	13	13	13	13
Vertebrae	40	40	39	39	39	40	39	39	39	40
Predorsal Length	71	70	71	70	70	72	70	71	72	71
Preventral Length	54	54	54	53	54	53	55	55	54	54
Preanal Length	71	69	70	70	70	71	70	72	70	72
Length of Head	25	24	24	24	25	26	23	26	25	25
Diameter of Eye	7	8	7	7	8	7	7	7	7	8
Interorbital Height	15	14	15	14	15	14	15	15	15	15
Length of Pectoral	56	55	54	55	57	55	58	56	56	57
Length of Ventral	18	19	18	18	19	18	19	18	18	18
Height of Body	18	17	18	18	19	19	19	18	18	18
Length of Barbel	—	—	—	—	—	—	—	—	—	—

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OBSERVATIONS ON *PINNAXODES FLORIDENSIS*, A NEW SPECIES OF PINNOTHERID CRUSTACEAN COMMENSAL IN HOLOTHURIANS

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ABSTRACT

Pinnaxodes floridensis is described from the northern part of the Gulf of Mexico. Sexual dimorphism in this species involves size, shape of the carapace and frontal area, and degree of fusion of ischium and merus of outer maxillipeds, as well as shape of the abdomen. Adult and pre-adult crabs were recovered from the cloaca and respiratory tree of the holothurian *Theelothuria princeps* where they normally filter their food from water circulated by the host. Juvenile crabs were recovered from anterior regions of the holothurian digestive tract. The ectoproct bryozoan *Triticella elongata* is reported from *P. floridensis*.

INTRODUCTION

While many protozoans, turbellarians, and mollusks, and the pearlfish (*Carapus* sp.) are well-known commensals of holothurian echinoderms, fewer cases of such a relationship have been recognized between decapods and holothurians. The decapods that have been reported as regularly inhabiting the cloaca of holothurians are crabs of the family Pinnotheridae (Bürger, 1895; Rathbun, 1918; Tesch, 1918; Tao, 1930; Chopra, 1931). These records all emanate from Indo-Pacific regions; no pinnotherid crabs have been reported from holothurians in the greater Atlantic Ocean.

This report concerns a member of the genus *Pinnaxodes* which inhabits the cloaca and respiratory tree of a holothurian on the northern coast of the Gulf of Mexico. The morphological variation of this species is discussed, with notes on its life history and commercial relationships.

OBSERVATIONS

On February 28, 1960, the authors found thousands of sea cucumbers in windrows on the outer beach near Fort Walton Beach, Florida, about 40 miles east of Pensacola. In the highest windrow, left by an unusually high tide, sea cucumbers were dry and dead; but on the lowest part of the beach, several specimens were found that were still capable of contraction. These holothurians were long (85 to 200 mm) and cigar-shaped, with a brown-colored dermis. Dr. Elisabeth Deich-

mann of the Museum of Comparative Zoology, Harvard College, kindly identified these holothurians as *Theelothuria princeps* (Selenka). This species was treated previously by Deichmann (1954) as *Holothuria princeps* Selenka. It typically occurs in sand at some depth, in the West Indian region. Dr. Deichmann indicates that numbers of this species are found only after storms, or by extensive dredging over a sandy bottom. The appearance of large numbers on this beach was undoubtedly due to a severe storm which had affected the area several days before.

By chance, an individual sea cucumber was collected which bore a small crab protruding from the posterior orifice. Subsequent examination of hundreds of specimens on the beach revealed only one other example of this situation. Further investigation revealed the common occurrence of a crab in the respiratory tree of this holothurian.

On the same day, in relatively quiet waters at East Pass, between Choctawatchee Bay and the northern Gulf of Mexico, numbers of *Theelothuria princeps* lay visible in shallow water near the shoreline. Most of these individuals were still alive. One hundred specimens were collected and dissected in search of commensal crabs. A longitudinal incision through the body wall exposed the digestive system, gonads, and respiratory (or anal) tree. Although the respiratory tree frequently was clogged with sand, contained commensal crabs often were visible through its transparent walls. Palpation of some of the sand-filled regions revealed other specimens. Forty-five of these relatively fresh holothurians harbored live commensal crabs. Although a holothurian usually contained but a single crab, pairs (one male and one female) were recovered in five cases.

Subsequent examination of two hundred *Theelothuria princeps* from Fort Walton Beach revealed crabs in various parts of the respiratory tree of 122 holothurians. These holothurians had been collected in an intermediate part of the beach, where they were dead but not completely desiccated. The 16 per cent difference in degree of infestation probably reflects their different fates, when washed inshore. Apparently, many of the holothurians at East Pass were incapacitated by the large amounts of sand taken in by respiratory currents; the resulting congestion of the respiratory system severely reduced the normal movement of water through the cloaca. Under these conditions, commensal crabs could escape into the water from flabby, narcotized holothurians. However, on the exposed beach, the effects of contrac-

tion of the cloacal sphincter and the effects of drying would likely trap these crabs inside. The proportion of infested holothurians from the beach (61 per cent) is probably closer to the original level of infestation, although, even there, escapes are possible, as indicated by the first two specimens observed, protruding from the cloaca.

In three hundred holothurians examined for the presence of commensal crabs, individuals were found in the enlarged cloacal region only thirteen times. The other crabs were found more anteriorly in the respiratory tree, which extends to the region of the teeth. In several cases, crabs found in the cloaca were males, but males were not restricted to this region.

Females were more abundant in this population. A total of 138 females were recovered as compared with 36 male crabs. This proportion approaches a 4:1 ratio between sexes. In view of the much larger number of females, one can deduce that each male usually copulates with more than one female, and that males must move about from host to host in search of females. As a consequence of this movement, males are subject to predation and similar hazards of life outside the host, and their numbers are likely reduced. Taking such mortality into account, the initial proportion of males probably was greater than that observed.

Description

A description follows based upon a series of 174 adult or sub-adult crabs. The female holotype and a series of paratypes are to be deposited in the U. S. National Museum, Washington, D. C.

Pinnaxodes floridensis, n. sp.

Carapace convex, smooth, minutely punctate, subcircular, slightly wider than long, widest anterior to mid-point, moderately calcified; line of hair extending lateral to buccal cavity; lateral margins indistinct, rounded.

Outer maxillipeds broad, with large palp (Figs. 2F, G); inner edge of the merus produced, forming a distinct angle; propodus larger than carpus, spatulate, about twice as long as wide; dactylus spatulate, two-thirds of length of the propodus, attached at side of propodus one-third of distance from proximal end, extending very slightly beyond its tip; both propodus and dactylus provided with long hairs.

Chelae (Figs. 2A, C, E) moderately long, smooth, minutely punc-

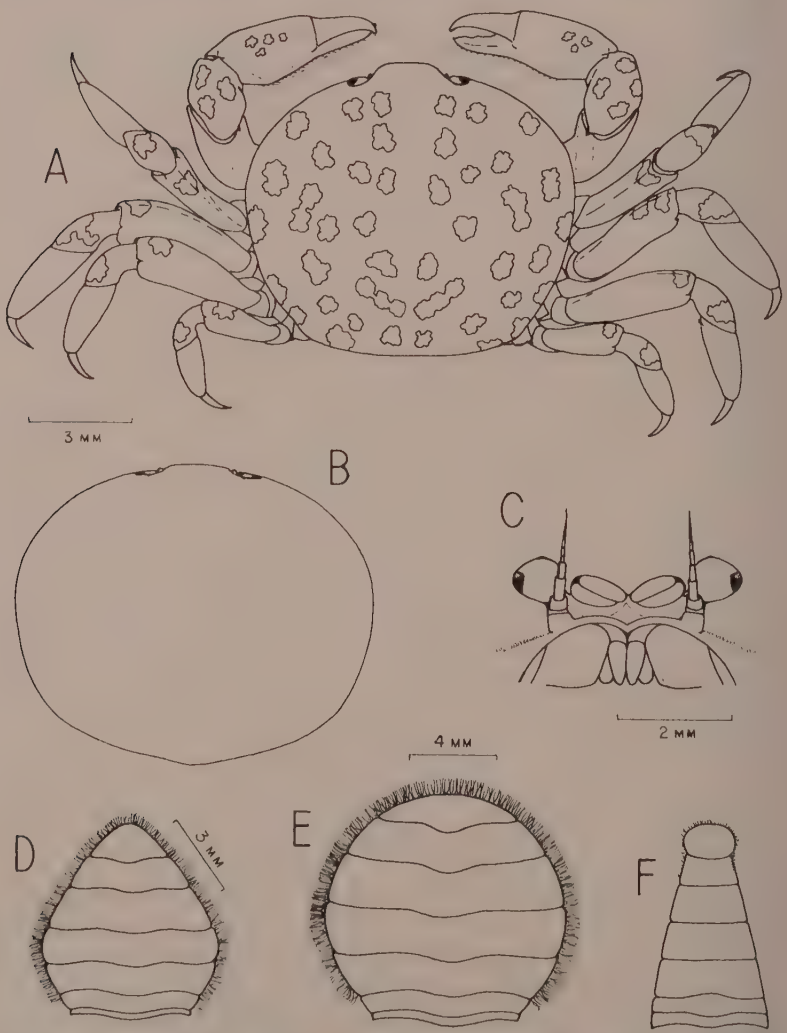

FIGURE 1. *Pinnaxodes floridensis*. A. Dorsal view of male showing color pattern in outline. B. Outline of adult female carapace. C. Frontal view of adult female. D. Abdomen of immature female. E. Abdomen of adult female. F. Abdomen of male. (A and B to same scale; D and F to same scale.)

tate; carpus slightly swollen; palm elongate, subcylindrical, increasing distally; fingers tapering, gaping through most of length, crossing at tips, somewhat spooned, with hairy internal crest; movable finger curved inward, with a basal tooth, and with inconspicuous dorsal tuft of hair near articulation point; immovable finger deflexed, with small sinus and tooth; line of stout hair extends along a low crest on lower edge of inner surface of palm, from near carpal articulation to lower margin of immovable finger (Fig. 2E).

Legs moderately short, relatively stout; second pair longest, shorter than chelae; fourth pair much the shortest; propodus elongate; dactylus curved, horny at tip; line of hair along dorsal crest and posterior ventral margin of merus, dorsal and ventral crests of propodus, and dactylus.

Color: many small red spots scattered on a white ground on dorsal surface, less developed on ventral surface, distributed in an imperfectly symmetrical pattern (Fig. 1A); spot of color typically on distal portion of carpal segments of walking legs and on merus of maxillipeds.

Measurements: carapace length of an ovigerous female—9.5 mm, carapace width—11.0 mm; carapace length of a male—8.0 mm, carapace width—9.0 mm; carapace length of largest immature female—8.75 mm, carapace width—9.75 mm.

Morphological variation.—As in most pinnotherid crabs, there is a marked sexual dimorphism in *Pinnaxodes floridensis*. This sexual dimorphism involves both overall size and structural differences in various parts of the body. In Figure 3, width measurements are presented for 115 females and 35 males. Because the frontal region is usually produced in males, measurements of width are more suitable for comparisons between sexes and indicate more accurately the overall size of the crabs than would length measurements. Although mature females are generally wider than males, there is much overlap in this dimension. Several immature females are larger than the smallest ovigerous females.

As mentioned above, the front is usually somewhat produced in males, the orbits being visible in dorsal aspect (Fig. 1A). In contrast, the front is usually deflexed in females, and the orbits are often concealed from dorsal view (Fig. 1B). This forward projection in males significantly contributes to the total length, producing a difference evident in width : length proportions. The carapace width of mature

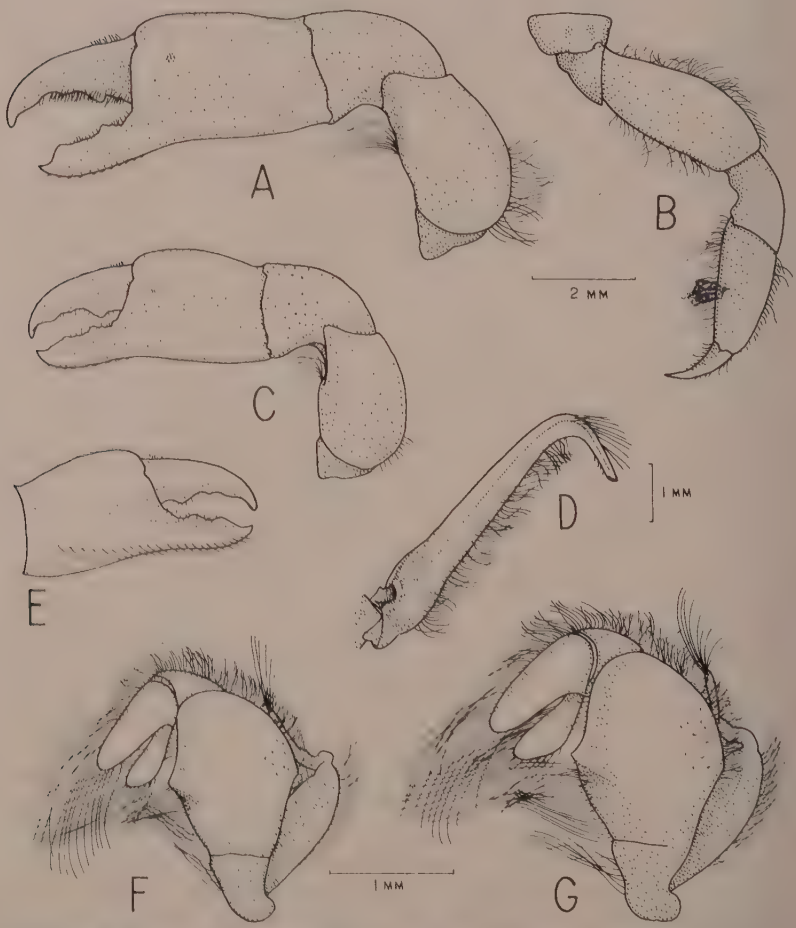

FIGURE 2. *Pinnaxodes floridensis*. A. Left chela, female, outer view. B. Third right leg, female. C. Left chela, male, outer view. D. First pleopod, male, left side. E. Manus of male left chela, internal view showing line of stout hair. F. Left maxilliped, male, outer view. G. Left maxilliped, female, outer view. (A, B, C and E to same scale; F and G to same scale.)

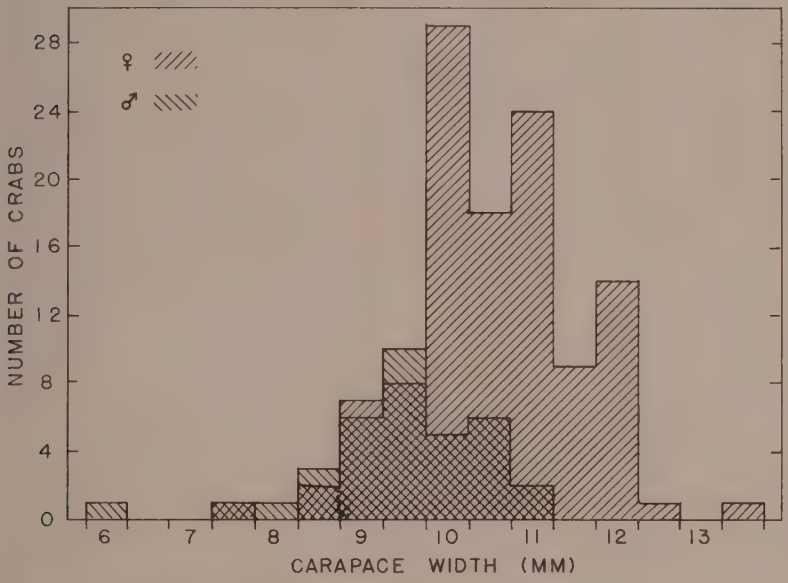

FIGURE 3. Frequency distribution of width measurements of 35 male and 115 female *Pinnaxodes floridensis*.

females is 1.14 to 1.25 times the length, while the carapace width of males is 1.03 to 1.19 times the length. The carapace of immature females more closely resembles the male form, the width being 1.11 to 1.20 times the length. Some of the smaller ovigerous females retain this slightly projecting front. Additionally, there is a significant difference in the interorbital distance between sexes. In males, the interorbital distance is considerably greater than in females of comparable size (as represented by width) (Fig. 4).

The carapace of mature females is higher and more convex than that of males. In males, there often are indistinct shallow grooves or depressions in the cardiac region, and the transition from dorsal to lateral surfaces is more distinct, being marked by a low ridge in the anterolateral region, although these characters are somewhat variable.

In the outer maxillipeds, one of the most important morphological variations occurs. In females, the fusion between the ischium and merus of this maxilliped is incomplete, a more or less distinct suture extending about two-thirds across the breadth of the endognath (Fig.

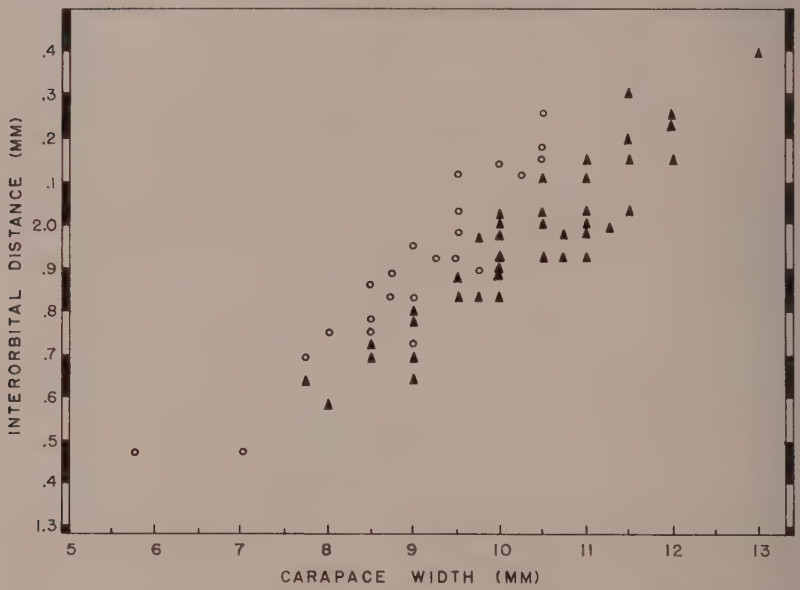

FIGURE 4. Relation of interorbital distance to width in *Pinnaxodes floridensis;* open circles indicate males, closed triangles indicate females.

2G). However, in males, this suture continues across the endognath, effecting a complete separation between the ischial and meral segments (Fig. 2F). This dimorphism in the maxillipeds is quite constant in the specimens examined.

The most obvious sexual difference in *P. floridensis* is the shape of the abdomen. Adult females possess a broad subcircular abdomen, fringed with hair (Fig. 1E), that effectively covers the ventral surface. Males possess a narrow, triangular abdomen with an enlarged, rounded terminal segment (Fig. 1F). Immature females possess a broadly triangular abdomen with a narrow anterior segment (Fig. 1D). The abdomen of an adult female is so large that in a non-ovigerous female, it extends forward to the buccal region, where it may be exposed to injury. In several cases, the abdomen of the female had suffered injury or erosion by the larger chela. In one specimen, the terminal segments of the abdomen were asymmetrically malformed as though such injury to its margin had been repaired with a subsequent moult. In this case,

the fifth and sixth segments were distinct on the left side, but fused on the right; the suture between the sixth and seventh segments was oblique, with the last segment skewed.

A number of stages in the reproductive cycle of the female were represented in our collections: immature females, females with full ovaries in which oviposition had not occurred, ovigerous females with fresh egg masses, ovigerous females with eggs displaying eyespots, and mature females with indications of having been ovigerous recently. The collection of such a wide range of stages indicates that oviposition is not restricted to a brief interval, but occurs over an extended period of time. Sperm were found in the spermathecae of an immature female, indicating that copulation had already taken place, well before the female assumes the mature form.

A number of tiny, nearly transparent juvenile crabs were also recovered from these holothurians. Because their presence was not suspected until late in the study, only a few holothurians were adequately examined for their presence. These yielded 22 specimens ranging from 1 to 3 mm in carapace width. Examination showed their maxillipeds, chelae, and pigment distribution to be essentially similar to corresponding characters of adults recovered from the respiratory tree. However, these juvenile crabs were found in the anterior part of the digestive system: in the buccal cavity, among the teeth, or in the anterior part of the esophagus in sand. They undoubtedly represent broods released earlier. Whether the holothurian digestive system is a normal path of invasion, a temporarily satisfactory orifice for would-be inhabitants of the cloaca, or another hazard for young crabs seeking the cloacal opening of their host is unknown.

These observations lead to the following tentative conclusions Evidently, males of *Pinnaxodes floridensis* move about from host to host in search of females. Copulation occurs within the host, before the female reaches maturity. After copulation, sperm are stored in the spermathecae of the female. Shortly after the female undergoes the maturation molt, oviposition occurs. Males persist in the population during the egg-bearing period, in contrast with the disappearance of *Pinnotheres ostreum* males after copulation (Christensen and McDermott, 1958). The eggs begin development, are released, and continue larval development in the water. In view of the collection of young stages from the host, this species must invade its host at an

early stage, perhaps the first crab which Christensen and McDermott regard as the infective stage in *Pinnotheres*.

Commensal Bryozoan

Of 174 adult crabs recovered, ten contained colonies of the stolonate ectoproct *Tricitella elongata* (Osburn) living commensally upon the legs and lateral surfaces of the carapace. This bryozoan has previously been reported in the gill chambers and on the legs of *Callinectes sapidus, Libinia* sp., and *Hepatus epheliticus,* and on the commensal crab *Pinnixa chaetopterana* found in the tubes of the polychaete *Chaetopterus variopedatus* (Maturo, 1957). Its collection on *Pinnaxodes floridensis* is a new record for that species, and an extension of its range from the middle Atlantic Coast (Massachusetts to North Carolina) to the northern Gulf of Mexico.

Relationship to Host

The relationship between *P. floridensis* and *T. princeps* is definitely commensal. While the crab receives protection and obtains food from water currents in the respiratory tree of the holothurian, the holothurian apparently does not suffer from its presence there. Because the respiratory tree opens at the posterior end of the holothurian, *P. floridensis* does not steal food that otherwise would be utilized by its host.

Like commensal crabs of the genera *Scleroplax* and *Pinnixa*, which are able to filter food from water by their feathery mouth parts (MacGinitie and MacGinitie, 1949), *Pinnaxodes floridensis* bears long hairs on its mouthparts. Utilizing bands of hair on the chelae and anterolateral regions, in addition to its feathery mouthparts, this species must be able to filter food particles from the water in a similar fashion.

Such a feeding method contrasts with that employed by most crabs of the genus *Pinnotheres,* which typically live in the mantle cavity of bivalves. The oyster crab, *Pinnotheres ostreum,* a typical example, ingests food which has been filtered and aggregated into strands by the oyster's gills (Christensen and McDermott, 1958).

The habitat of *P. floridensis* may appear to be a poor location when compared with that of other commensal crabs. In the branchial region of bivalves, in the test of tunicates, and in the U-shaped tube of *Chaetopterus,* commensal crabs are presented a unidirectional

flow of water. However, because the holothurian circulates water in and out of the same aperture, the flow in the holothurian respiratory system must reverse direction frequently. Certain crabs of the genus *Pinnixa* may live in worm holes in loose sand where the flow of water similarly reverses at intervals, as it does in the respiratory tree of a holothurian. The many crabs which obtain their food directly or indirectly from a unidirectional current are probably more efficient in their food gathering operations than those species obtaining their food from such a reversing current. The presence of sizable colonies of the bryozoan *Triticella elongata* on the carapace of *P. floridensis* indicates that a plentiful supply of food occurs in water circulating in the respiratory system. This bryozoan feeds on plankton, and is often found in the branchial chamber of much larger decapods, where it collects food from respiratory currents maintained by its decapod host.

Discussion

Because the degree of fusion of ischium and merus of the maxilliped is an important character in the separation of genera in the Pinnotheridae, the observed disparity between the sexes could lead to individual specimens of this species being placed in different genera, or even subfamilies. In her definition of the genus *Pinnaxodes*, based on known species, Rathbun (1918) noted that the merus is either fused or partly fused with the ischium of the outer maxilliped. Whereas the female *P. floridensis* falls within this definition, the male does not fit because of the complete separation of merus and ischium. On the basis of other characters, *floridensis* should be placed in *Pinnaxodes*. Therefore, the definition of the genus given by Rathbun is here emended to account for the condition of the male maxilliped in *floridensis*: merus and ischium fused, partly fused, or separate.

In her treatment of the grapsoid crabs of America Rathbun (1918) included a species from Brazil (*P. tomentosa* Ortmann) in the genus *Pinnaxodes*. As she suggested at that time, *P. tomentosa* should be considered a species of *Pinnotheres*. This leaves *Pinnaxodes floridensis* the only known representative of the genus in Atlantic waters.

The brief, superficial description of *Pinnotheres hirtimanus* Milne-Edwards (1853) would apply to *Pinnaxodes floridensis*, particularly in regard to the possession of a row of hair on the chelae. Because that species had been described twelve years before the genus *Pinn-*

axodes was separated from *Pinnotheres,* and because it was poorly known, it was possible that this holothurian commensal was *P. hirtimanus*. Through the generous cooperation of Dr. Jacques Forest of the Paris Museum, specimens of *Pinnaxodes floridensis* have been compared with the type and only known specimen of *Pinnotheres hirtimanus*. Whereas the carapace of that species is thin and fragile, the carapace of *Pinnaxodes floridensis* is firm; there are many additional characters that separate these two entities.

Pinnaxodes floridensis is to be compared with two Pacific Coast representatives of this genus, *P. chilensis* (Milne-Edwards) and *P. silvestrii* (Nobili). While the legs of *P. floridensis* are much shorter than in *chilensis,* they are not as stout as in *silvestrii;* additionally, details of the maxillipeds separate it from both of these species. Although *P. floridensis* shares a coloration of red spots with *Opisthopus transversus* Rathbun, also of the Pacific Coast, a different shape to the carapace and maxillipeds readily serve to distinguish that somewhat related species.

Acknowledgments

The authors wish to express their appreciation to Dr. Elisabeth Deichmann of the Museum of Comparative Zoology, Harvard, for identifying the holothurian; and to Dr. Jacques Forest of the Muséum National d'Histoire Naturelle, Paris, for comparing specimens with the type of *P. hirtimanus*.

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ANATOMY AND SEXUAL DIMORPHISM OF THE SWIM BLADDER AND VERTEBRAL COLUMN IN *OPHIDION HOLBROOKI* (PISCES: OPHIDIIDAE)[1]

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Abstract

The Family Ophidiidae exhibits marked sexual dimorphism among a number of its species. An example of this is found in *Ophidion holbrooki* (Putnam, 1874) in which the vertebral column and swim bladder of the female and male differ markedly. Both sexes have the dorsal area of the first vertebra modified to form a winglike process. In the male the third to the sixth vertebrae are modified to form a supporting mechanism in which a free "bone," referred to as the rocker, is seated. In the female there is no supporting mechanism or rocker. However, the third vertebra has a modified transverse process which attaches to the swim bladder.

The physoclistous swim bladder of the male and that of the female are similar except for the anterior portion. The anterior end in the male swim bladder is associated with the rocker and in the female the anterior end has two round hollowed protuberances.

In both sexes three similar sets of muscles are found in association with the swim bladder, the vertebral column, and the skull. One set of muscles differs in that in the male the set attaches to and rotates the rocker while in the female the place of attachment is directly to the swim bladder.

A description is given of the functional morphology of the muscles, of the innervation of the associated musculature and the swim bladder by the vagus nerve, and of the blood supply of the swim bladder.

The swim bladder probably functions as a sound producing organ in both sexes. No live material was studied and therefore no evidence is available to support or reject this theory.

Introduction and Acknowledgments

The Family Ophidiidae exhibits marked sexual dimorphism among a number of its species. This has proved valuable in diagnosing species and may provide important clues to the various phyletic lines within the group. Briggs and Caldwell (1955: 288) have suggested that this ". . . may be a fundamental characteristic of the entire family." "The generic affinities and grouping of ophidiids are much confused and even a partial discussion of this problem is not feasible at the moment" (Böhlke and Robins, 1959: 41). In an attempt to help reduce the confusion and to present further knowledge of this group, a study of the anatomy of the swim bladder and vertebral column in *Ophidion holbrooki* (Putnam, 1874) was undertaken.

[1]Contribution No. 321 from the Institute of Marine Science, University of Miami. This paper was submitted in partial fulfillment of the degree of Master of Science, University of Miami, Coral Gables, Florida.

Dr. C. Richard Robins examined the holotype of *Ophidion holbrooki* at the Museum of Comparative Zoology and verified the identification of the specimens used by the author for this study. The specimens were all taken from waters near the type locality which is Key West, Florida. The over-all geographic distribution of this species remains to be determined.

I wish to express my thanks to Andrew E. Jones and John Tweedy of the University of Miami Institute of Marine Science for collecting all material used in this study.

I am indebted to Edward M. Nelson of the University of Puerto Rico, San Juan, Puerto Rico, for valuable advice in the initial stages of this study.

Thanks are also due Dr. Francis J. Bernard for making the serial sections of the swim bladder, helping to stain them, and to both him and to Dr. Charles E. Lane for aid in the interpretation of the slides. Dr. Lane has also been an advisor in many other capacities. I wish to also thank Dr. Donn E. Rosen, Curator of Fishes, Florida State Museum, for advice. I wish to express my appreciation to the members of my thesis committee, Drs. C. Richard Robins, Gilbert L. Voss, Charles E. Lane, and C. P. Idyll, for their helpful comments on the manuscript. Walter R. Courtenay, Jr. provided Figure 1 and Fortune Bosco provided the Italian translation of a paper by Facciolá (1933).

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A special word of thanks is due to Dr. C. Richard Robins, Curator of Fishes at the University of Miami Marine Laboratory, who first suggested the problem, and without whose help this work could not have been completed.

Materials and Methods

The specimens used in this study of *Ophidion holbrooki* were taken mainly from two collections made on shrimp trawlers fishing the Dry Tortugas shrimp grounds west of Key West, Florida. One collection was at latitude 24°45′ to 50′ N, longitude 82°10′ to 30′ W, in 10 fathoms (UMML 4720) and the other at latitude 25°10′ N, longitude 82°13′ W, in 14 fathoms and latitude 24°49′ N, 82°12′ W, in 13 fathoms. A large collection was also made at a depth of 40 feet from

Hawk Channel near Bahia Honda Bridge in the Florida Keys (UMML 6050). The fish were preserved in 10 per cent formalin and were catalogued and deposited in the collection of fishes at the Institute of Marine Science, University of Miami.

A number of skeletons were prepared for study by placing specimens in boiling water for a few minutes and then dissecting out the skeleton. For this purpose ten males (UMML 6531, 6532, 6533, 6534, 6535, 6536, 6537, 6539, 6540, 6541) and one female (UMML 6538) were taken from the second collection mentioned above which was made at the Dry Tortugas shrimp grounds. Three males (UMML 6528, 5893, 6230) and four females (UMML 6529, 6542, 6051, 6543) were used from UMML 4720. The skeletal drawings were made from specimens which represented the group as a whole in appearance.

A large series of specimens was examined before drawing the musculature and swim bladder. The same is true in regard to the identification of the important blood vessels and nerves. All dissections for the drawings were made on the right side of the fish and the specimens were taken from lots UMML 4720 and UMML 6050. Four females and twelve males were used from the former while one female was used from the latter.

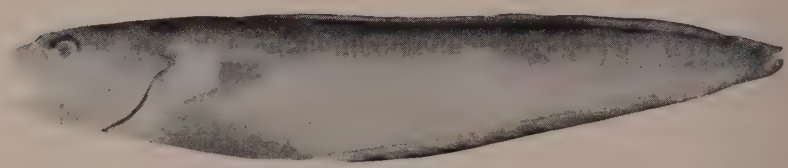

FIGURE 1. *Ophidion holbrooki* (Putnam, 1874). UMML 5080, Dry Tortugas, adult male, 164 mm standard length.

Injection of the circulatory system with India ink thickened with gelatin was attempted, but the small size of the blood vessels required such a fine hypodermic needle to inject this mixture that the thickened ink could not be forced into the blood vessel sufficiently fast before the gelatin hardened, thus clogging the needle and the vessels. This procedure was abandoned and only India ink was used. The latter method would have been more successful had the blood vessels not been so obstructed with old blood or if it had been possible to obtain fresh specimens from which the blood could have been drained. For

these reasons, little can be said of the blood supply to the areas in question.

The nerves were very difficult to work with because of their fragile nature. Repeated dissections were made on different specimens and attempts to trace the more important nerves to their origin yielded some success.

Sections 10 microns thick were made through the more pertinent parts of the swim bladders of both males and females, such as the

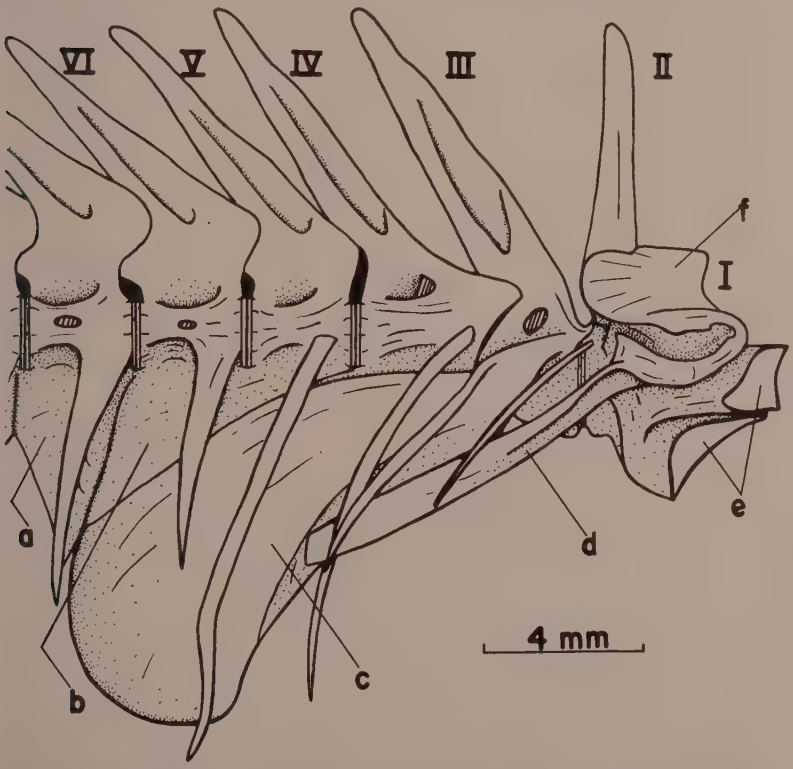

FIGURE 2. Lateral view of anterior section of vertebral column of the male *Ophidion holbrooki*. a: Ventral bony plate of seventh vertebra. b: Ventral bony plate of sixth vertebra. c: Lateral wall of rocker's supporting mechanism orginating from third vertebra. d: Winglike process of first vertebra. e: Facets articulating to occipital condyle. f: Dorsal aspect of winglike process forming neural arch.

rete mirabile and gas gland, the posterior end of the swim bladder, the rocker in the male, etc. These parts were first decalcified in Bouin's solution and then stained by the hematoxylin-eosin method. Unfortunately, the specimens were originally preserved in 10 per cent formalin for several months with the result that histological details were difficult to see. For this reason the histological results are inconclusive. Whole mounts were also made of the fibers of important muscles. The mounts were stained with Harris' hematoxylin to determine whether the muscles were striated or smooth.

Considerable effort was spent on a study of the rocker of the male. A sagittal section of the rocker was prepared by grinding one side down with a whetstone. Drawings could be made of the central or inside area.

Radiographs were made of the lateral and ventral sides of several specimens of both males and females to facilitate the study of the rocker in the male and the vertebral column in both sexes.

When a particular structure appears in more than one drawing, the same letter is used to designate it. Roman numerals are also used to designate the vertebrae.

Gross Anatomy of the Male

Swim Bladder.—The swim bladder of the male (Fig. 8) is retroperitoneal and is found directly beneath the vertebral column anteriorly, while posteriorly it is separated from the latter by the kidneys. The swim bladder is physoclistous, extends the length of the body cavity, and consists of one chamber.

There are two distinct layers of tissue composing the bladder wall. The outer is a heavy white layer while the inner is thin and transparent. The former is also thicker posteriorly than anteriorly. Anteroventrally the smooth milky white wall of the swim bladder, which has an over-all silky sheen, changes to a thin transparent membranous area circular in outline but still composed of two layers. The outer layer of this membranous area, which is very thick posteriorly and becomes thin anteriorly, attaches firmly to an area lying dorsally and dorsolaterally to an aperture in the posterior face of a "bone" found immediately anterior to the membranous area of the swim bladder (Fig. 5B). (This "bone" will be referred to as the rocker, Figs. 6, 7, 8, 5B, 5C, and 5D, and is described in more detail below). At the same time, the inner layer of the bladder wall

continues from all sides through the aperture and into the interior of the hollow of the rocker, thus lining its entire inside.

The outer layer of the dorsal wall of the swim bladder is firmly attached to the ventral surfaces of the seventh through the ninth vertebrae. It also attaches to the posterior end of a bony plate formed on the ventral surface of the centrum of the fourth vertebra, but extending further posteriorly, and to two bones which form the lateral walls of the plate (Figs. 2, 3 and 6). The antero-lateral wall of the bladder is attached by a broad ligament to the rib of the sixth vertebra. This rib in turn is attached by a ligament to the rib of the seventh vertebra.

The dorsal wall of the posterior half of the swim bladder slants dorsoventrally in a posterior direction, so that the posterior end of the

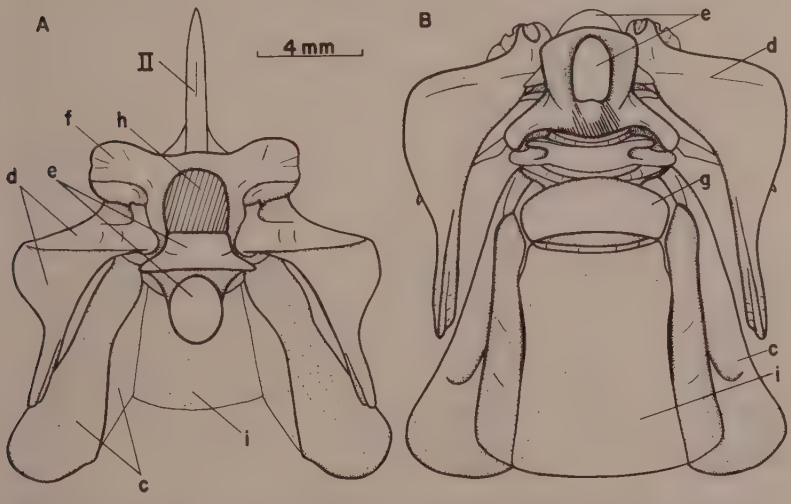

FIGURE 3. A. Anterior view of anterior section of vertebral column of the male *Ophidion holbrooki*. c: Lateral wall of rocker-supporting mechanism originating from third vertebra. d: Winglike process of first vertebra. e: Facets articulating to occipital condyle. f: Dorsal aspect of winglike process forming neural arch. h: Passage for spinal cord. i: Continuous bony plate of rocker-supporting mechanism originating from fourth vertebra. B. Ventral view of anterior section of vertebral column of the male *Ophidion holbrooki*. c: Lateral wall of rocker-supporting mechanism originating from third vertebra. d: Winglike process. e: Facets articulating to occipital condyle. g: Anterior wall of rocker-supporting mechanism formed from third vertebra. i: Continuous bony plate of rocker-supporting mechanism originating from fourth vertebra.

swim bladder is pointed. From histological sections, the pointed end of the swim bladder apparently has no opening which would connect the swim bladder lumen with the coelom nor is there any type of communication with the exterior by a ventral tubular structure originating from the posterior end as is reported in many clupeoid fishes (Dehadrai, 1960).

Blood vessels penetrate the swim bladder in the middle of its ventral side just at the point where the outer layer begins to thin to help form the membranous area (Fig. 8). These are the arterial and venous vessels which supply and drain the rete mirabile and the gas gland. The rete mirabile and the gas gland, both located on the inside ventral surface of the swim bladder, together form a structure shaped like a half circle with its rounded surface pointing anteriorly. The rete mirabile forms the inner layer of this half circle with the gas gland forming the outer layer and overlapping the rete mirabile. Woodland (1911) describes and illustrates the rete mirabile and the gas gland of *Ophidion barbatum* (Linnaeus) which is very similar to that of both sexes of *Ophidion holbrooki*. Also the transverse sections made of the rete mirabile and the gas gland in *Ophidion holbrooki* resemble those of *Ophidion barbatum*, which were illustrated by Woodland (1911).

The arterial supply to the swim bladder is by the coeliaco-mesenteric artery which arises from the dorsal aorta. The venous blood leaves the rete mirabile by means of a feeder vessel to the hepatic-portal system. The dorsal surface of the swim bladder is largely drained by one main branch of the posterior cardinal vein. Efforts to inject the dorsal aorta were unsuccessful, but presumably there are small vessels from the dorsal aorta supplying the dorsal area of the swim bladder as described by Jones and Marshall (1953) for the physoclistous swim bladder of teleosts. The above description of the vessels supplying the swim bladder follows closely that of Jones and Marshall (1953: 24).

Efforts to locate the oval in both the male and the female met with no success. Serial sections of the extreme posterior end of the swim bladder were made and of the area where the feeder vessel of the posterior cardinal vein leaves the swim bladder in both sexes, but there was no indication that the oval was in these areas.

Vertebral Column.—The dorsal portion of the first vertebra is modified to form a winglike process which slants dorsoventrally (Figs. 2, 3A and B). The portion of this structure which is an immediate part of the first vertebra forms a neural arch without a neural spine and

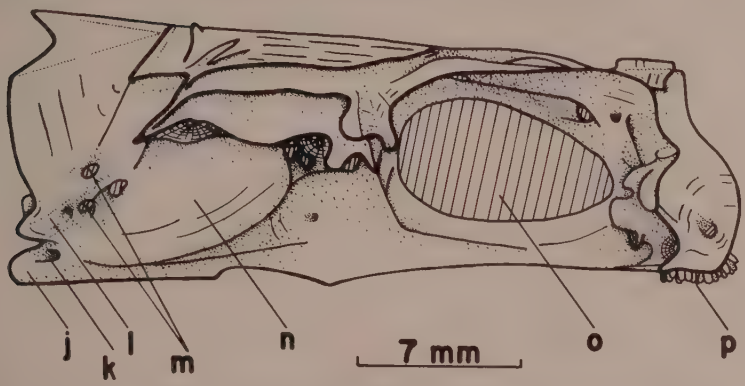

FIGURE 4. Lateral view of skull of *Ophidion holbrooki*. j: Basioccipital. k: Point of attachment for Baudelot's ligament. l: Exoccipital. m: Nerve foramina from which branches of vagus nerve exit. n: Otic region. o: Orbit. p: Teeth.

provides attachment on its surface for a muscle, M_2 (Fig. 7). The remainder of the winglike process projects transversely and then curves posteriorly. The ventral aspect of the portion projecting transversely provides a surface for the attachment of another muscle, M_3 (Figs. 7 and 8). In boiled specimens the entire winglike process may be removed as one piece from the first vertebra.

Starting with the third vertebra and ending with the sixth, one can see the important modifications which contribute to the support of the rocker. The ventral side of the centrum of the third vertebra forms an anterior wall (of the supporting structure) which slants anteroventrally (Fig. 3B). Starting with the fourth vertebra and ending with the sixth, a continuous bony plate is formed which is attached to the ventral surface of the centrum of the fourth vertebra but not to those of the fifth and sixth, as explained below. This plate is slightly concave and slants gradually posteroventrally (Figs. 3A and 3B).

An extra bony plate (Fig. 2) is formed on the ventral surface of the centrum of the fifth vertebra and separates the larger bony plate from the latter. This smaller plate extends to the end of the sixth vertebra but is not attached to it and acts as a connection between the larger plate and the fifth vertebra since the former, as it passes posteriorly, slopes away from the vertebral column.

From the ventral side of the sixth vertebra another bony modification (Fig. 2) is formed which overlaps the plate of the fifth vertebra

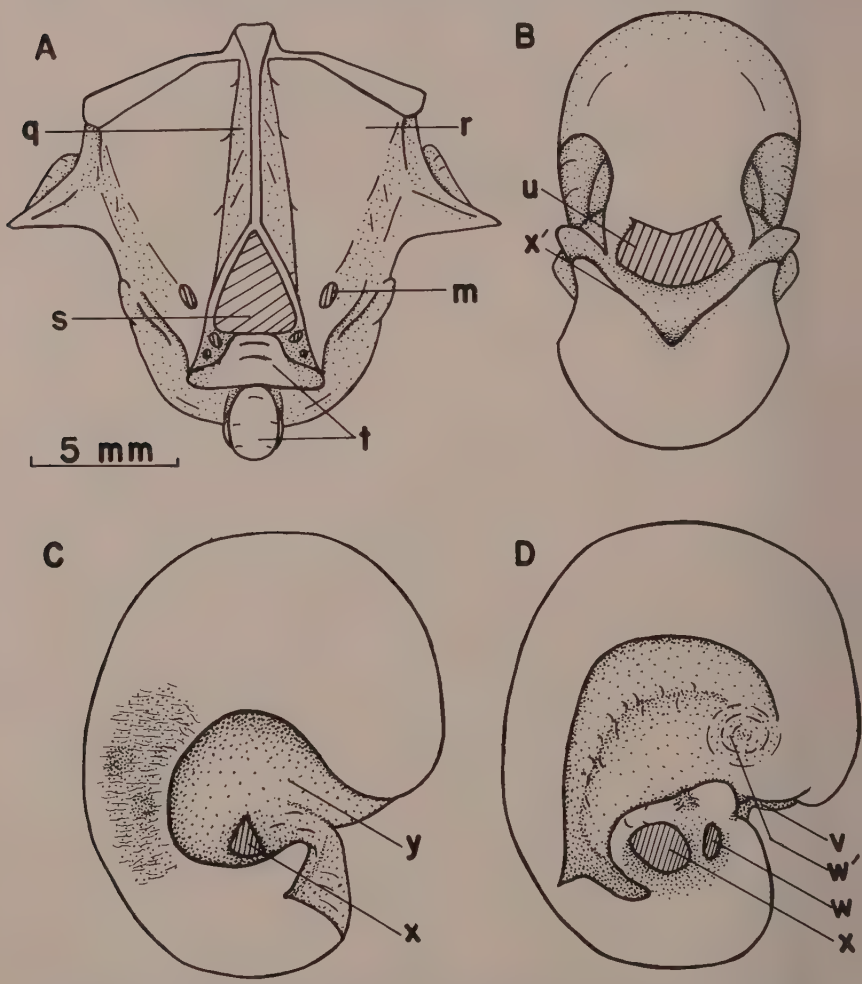

FIGURE 5. A. Posterior view of skull of *Ophidion holbrooki*. m: Nerve foramen from which branch vagus nerve exits. q: Supraoccipital. r: Epiotic. s: Foramen magnum. t: Occipital condyle. B. Posterior view of rocker of male (scale as for A). u: Aperture leading to inside. x′: V-shaped area where outer layer of swim bladder attaches. C. Sagittal section of rocker of male showing internal features (scale as for A). x: Aperture on side which is covered by swim bladder material externally. y: Hollow interior of rocker. D. Lateral view of rocker of male (scale as for A). v: Posterior aperture. w: Point of attachment of ligament from posterior end of winglike process. w′: Point of attachment of tendon from muscle M_1. x: Aperture on side which is covered by swim bladder material externally.

and then attaches on each side to the lateral walls of the support of the rocker (described below) and to the ribs of the sixth vertebra. This process extends the same length as the plate of the fifth vertebra.

On the ventral surface of the centrum of the seventh vertebra another bony plate is formed which extends out to the sides and attaches to the ribs of the same vertebra. This also takes place on the eighth vertebra but the plate is smaller. The anterior face of the plate of the seventh vertebra rests on the posterodorsal surface of the plate of the sixth vertebra while there is no overlapping between the plates of the seventh and eighth vertebrae. Only their borders touch.

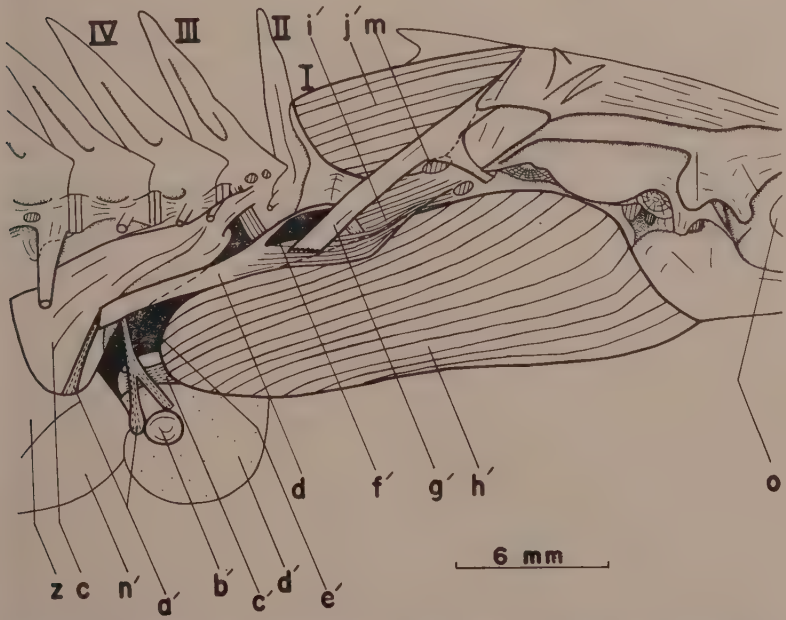

FIGURE 6. Lateral view of swim bladder and associated superficial musculature of the male *Ophidion holbrooki*, a′: Ligament. b′: Material similar to wall of swim bladder covering aperture in side of rocker. c: Lateral wall of rocker-supporting mechanism originating from third vertebra. c′: Tendon. d: Winglike process of first vertebra. d′: rocker. e′: Jellylike material surrounding rocker. f′: Ligament connecting cleithrum and winglike process. g′: Supracleithrum (covering cleithrum), h′: Muscle M_1. i′: Muscle M_3. j′: Muscle M_2. m: Foramen for branch of vagus nerve. n′: Transparent area of swim bladder. o: Orbit. z: Swim bladder.

Laterally attached to the larger bony plate which originates from the third vertebra are two bones which form the lateral walls of the supporting structure for the rocker (Figs. 2, 3A, 3B, 6 and 7). Each lateral wall originates from the third vertebra at about the same locality as the ribs of the other anterior vertebrae. This process extends outwardly and dorsoventrally in a posterior direction. It is narrow proximally and has a rib projecting from its dorsal edge, and as it reaches the anterior part of the large bony plate it attaches to the side of the plate. As the process continues posteriorly it thickens and becomes wider laterally. The posterior surface of each lateral wall is somewhat rounded and pitted (this is where the outer layer of the swim bladder wall attaches). It is probable that these lateral walls represent the transverse process from which the pleural rib originates.

A ligament connects each lateral wall of the rocker-supporting mechanism (this posterior attachment is to the outer side of the support's posteroventral portion at the boundary which marks the end of the attachment of the outer layer of the swim bladder wall) to the posterior end of the winglike process of the first vertebra (Figs. 6 and 7). There is a ligament which also connects the outer and anteroventral surface of the portion of the winglike process projecting transversely with the inner and superior portion of the cleithrum (Figs. 6, 7, and 8).

At the point where the supracleithrum joins to the cleithrum (the former lies externally to the latter) Baudelot's ligament attaches to the inner surface of the supracleithrum (Figs. 7 and 8). From there the ligament proceeds posteriorly, passes around the cleithrum, and then advances to the basioccipital where it attaches. While proceeding to the basioccipital it passes horizontally through a muscle, M_3, dividing the latter into dorsal and ventral segments.

There is a ligament which attaches to the ventral surface of the posterior end of the winglike process and then proceeds ventrally to attach to the rocker in two different places. It accomplishes this by dividing into two ligaments before reaching the rocker (Figs. 6, 7, and 8).

Muscles.—There are three muscles which are associated with the swim bladder and all three attach to localities on the posterior half of the skull. In Figs. 4 and 5A the pertinent parts of the skull are named. A strong tendon of one muscle inserts into the rocker at a position just

anterodorsal and lateral to the posterior opening of the rocker (Figs. 6, 7, and 8). This muscle (M_1) passes forward and attaches broadly to the anterior half of the otic region of the skull and also to the area which is immediately anteroventral to the otic region. This muscle is composed of striated fibers and is round and long in form. During dissection it can be seen very distinctly.

A second muscle (M_2) has a wide attachment on the dorsal aspect of the winglike process of the first vertebra and also on the epiotic area of the skull (Figs. 6 and 7). The muscle is composed of striated fibers, is large, thick, and very distinct from the surrounding musculature.

There is a third muscle (M_3) which acts as a connection between the winglike process and the skull (Figs. 6, 7, and 8). It has a broad attachment to the anteroventral surface of the part of the wing protruding transversely and attaches widely to the skull at about the exoccipital region and the posterodorsal portion of the otic region. There are three small foramina formed in a line in the exoccipital region (Fig. 4). A ridge immediately above the foramina forms the dorsal boundary for this muscle (M_3). The innermost segment of the muscle attached to the ventral part of the wing continues posteriorly and attaches by a very small tendon to the proximal ventral edge of the bone which arises from the lateral side of the centrum of the third vertebra and which forms a lateral wall of the supporting mechanism for the rocker (Fig. 8). This is the muscle through which Baudelot's ligament passes horizontally, dividing the outer segment into dorsal and ventral portions. This muscle also has striated fibers.

Another muscle, not signficant to the function of the swim bladder, but which is present in the area of the first three muscles, is the retractor muscle of the upper pharyngeal jaw (Figs. 7 and 8). This muscle takes origin from the lateral side of the centrum of the third vertebra at a point immediately below the origin of the bone forming a lateral wall of the supporting mechanism for the rocker. The muscle is long, narrow, distinct in appearance, has striated fibers, and is broadly and strongly inserted on the centrum of the third vertebra.

Rocker and Its Supporting Mechanism.—In the male the third to the sixth vertebrae have bony modifications which combine to form the supporting mechanism or seat of the rocker. The individual bones forming this mechanism were described in the section on the vertebral column and are illustrated in Figures 2, 3A, and 3B.

The rocker, illustrated in detail in Figures 5B, 5C, and 5D, is an object whose composition has not yet been determined. As explained earlier, serial sections lacked good histological detail. It would appear to be bone except that it lacks the hardness and permanence of bone and does not take alizarin stain. Possibly it is cartilage impregnated with calcium salts. The external surface of the rocker is very smooth except for the lateral sides where a deep furrow is formed. This furrow is filled with a substance which is flexible and non-brittle, as can be seen when pressure is applied. At the posterodorsal end of the furrow a depression exists for the attachment of the tendon of muscle M_1 (Figs. 6 and 7). Also, on the side and just ventral to this area an out-

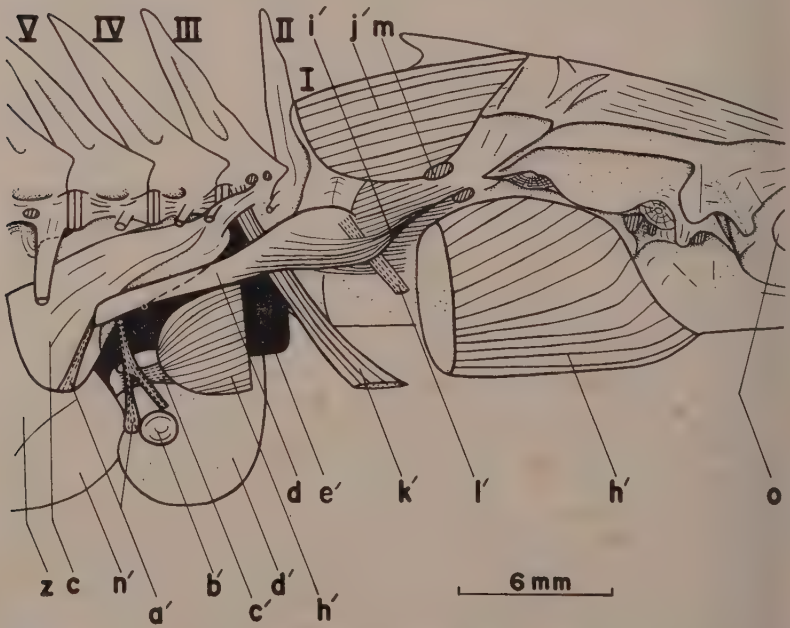

FIGURE 7. Lateral view of swim bladder and associated deep musculature of the male *Ophidion holbrooki*. a′: Ligament. b′: Material similar to wall of swim bladder covering aperture in side of rocker. c: Lateral wall of rocker-supporting mechanism originating from third vertebra. c′: Tendon. d: Winglike process of first vertebra: d′: Rocker. e′: Jellylike material surrounding rocker. h′: Muscle M_1. i′: Muscle M_2. j′: Muscle M_2. k′: Pharyngeal retractor muscle. l′: Baudelot's ligament. m: Foramen for branches of vagus nerve. n′: Transparent area of swim bladder. o: Orbit. z: Swim bladder.

pocketing of white material can be seen (Figs. 6, 7, and 8). This exists on both sides of the rocker and the material resembles the outer layer of the swim bladder. This material originates from within the tissue of the rocker and is firmly embedded. Upon its removal an opening can be seen leading into the inside of the rocker, the latter being hollow (Figs. 5C and 5D). Posterior to this opening there is a depression for the attachment of one of the two branches of the liga-

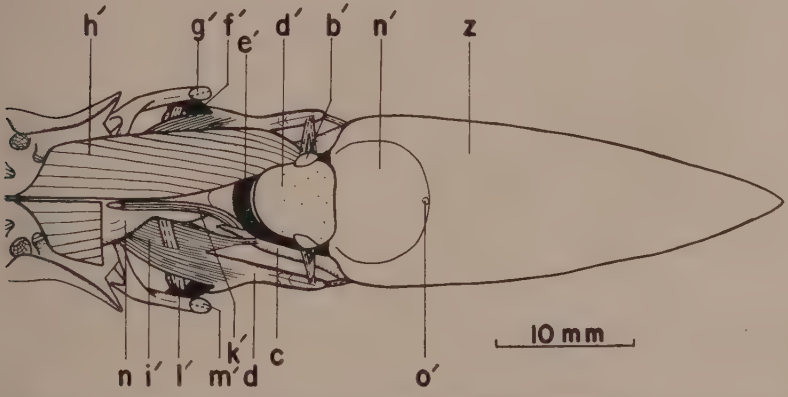

FIGURE 8. Ventral view of swim bladder and associated musculature of the male *Ophidion holbrooki*. b′: Material similar to wall of swim bladder covering aperture in side of rocker. c: Lateral wall of rocker-supporting mechanism originating from third vertebra. d: Winglike process of first vertebra. d′: Rocker. e′: Jellylike material surrounding rocker. f′: Ligament connecting cleithrum and winglike process. g′: Supracleithrum. h′: Muscle M_1. i′: Muscle M_3. k′: Pharyngeal retractor muscle. l′: Baudelot's ligament. m′: Cleithrum. n′: Otic region. o′: Area of penetration of blood vessels supplying and draining rete mirabile and gas gland. z: Swim bladder.

ment that originates from the posterior end of the winglike process (Figs. 5D, 6, 7, and 8). The other branch attaches at approximately the same level but anterior to the opening in the side of the rocker. The tendon of muscle M_1 which attaches to the rocker passes internally to the branching ligament connecting the winglike process to the rocker.

Anteriorly the rocker is completely closed while posteriorly there is a large aperture (Fig. 5B). As described before, the outside layer of the swim bladder attaches to an area just dorsal and dorsolateral to this opening. This area is a long shallow groove lying across the posterior face of the rocker and is in the shape of a wide V with the

apex forming a deep indentation. The groove may represent the point of union of two segments of the rocker. The inside layer of the bladder passes through the aperture from all sides and lines the inside of the rocker, including the lateral white outpocketings. A sagittal section showing the inside area of the rocker is presented in Figure 5C.

The supporting mechanism or seat of the rocker is lined on the inside with a thick material which is jellylike in consistency but whose composition is not known by the author. It is not brittle like cartilage nor is it granular like developing bone. It is very flexible. Besides lining the inside of the rocker, this material attaches firmly to the ventral edges of the lateral and anterior walls of the rocker mechanism. After its attachment it then continues ventrally, forming walls which extend beyond the edges of the supporting mechanisms (Figs. 6, 7, and 8). It is also attached by a strong ligament at its most anterior point to the ventral surface of the centrum of the second vertebra. This jellylike material thus forms a pocket in which the rocker sits. It encloses the dorsal face and the dorsal portions of the lateral and anterior faces of the rocker. The posterior face (except for the extreme dorsal portion) with its aperture is left free for the attachment of the swim bladder. The jellylike material adheres closely to the rocker holding it in place, yet permitting and lubricating its anterior-posterior rotation on a transverse axis.

Very small blood vessels penetrate the sides of the rocker where the substance filling the furrow is found. Efforts to trace these vessels were unsuccessful, except for one which was traced to a branch of the dorsal aorta. It is not known whether nerves penetrate here, but very possibly they do.

Gross Anatomy of the Female

Swim Bladder.—The swim bladder of the female (Fig. 13) is similar in position to that of the male. It is retroperitoneal (found directly below the vertebral column anteriorly, while posteriorly it is separated from the latter by the kidneys), physoclistous, consists of one chamber, and extends the length of the body cavity. The female swim bladder wall is not so sturdy as that of the male and tears much more easily during dissection.

The general appearance of the female swim bladder is the same as the male except for the anterior end. There is no rocker (or modified bones) here to form a supporting mechanism for a rocker, nor is there

a transparent membranous area. Instead, there are two thick rounded and hollow proturberances on the anterior end of the swim bladder, one of the left and one on the right. The lumen of the swim bladder is continuous with the chambers in each of these protuberances (Figs. 11, 12, and 13).

The anterior end of the swim bladder immediate to and including the two thick bulbous areas is rigid in comparison with the rest of the swim bladder, which is flexible. There is a short, thick, longitudinal ridge formed near the anterior end in the middle of the ventral surface of the bladder (Fig. 13). In the female as in the male there is a winglike process on the first vertebra (Figs. 9, 10A, and 10B). It is somewhat different in shape and will be described in detail later.

The female swim bladder is composed of two distinct layers. As in the male, the inner layer is thin and transparent while the outer is heavy and white. The inner layer lines the entire interior of the swim bladder, including the bulbous areas located anteriorly.

The outer layer of the dorsal wall of the swim bladder is firmly attached to the ventral surface of the second through the ninth vertebrae. The third vertebra is modified so that a transverse process is formed from whose dorsal surface a rib projects. The inside of the distal half of this process has a triangular-shaped area which extends inward towards the vertebral column but ends abruptly some distance from the latter (Figs. 9, 10A and 10B). The ventral surface of the distal portion of the transverse process and of the triangular-shaped area adheres closely to the dorsal surface of the swim bladder (Figs. 11 and 12) as can be seen by the pitted areas of the bone where the swim bladder inserts. For the same reason the ventral surfaces of the second through the ninth vertebrae are also very pitted (Fig. 10A).

The rib of the second vertebra is attached by broad strong ligaments to the swim bladder, to the anterior edge of the transverse process of the third vertebra, and to the posterior edge of the winglike process of the first vertebra (Figs. 11 and 12). The disto-ventral surface of the winglike process is also firmly attached by means of a very strong ligament to the swim bladder at a point just behind the origin of the bulbous area.

The extreme posterior end of the female swim bladder appears to be thicker in composition and less pliable than the rest of the bladder (except for the extreme anterior end). This end will stretch, however, with even greater elasticity and over a greater area than in the male.

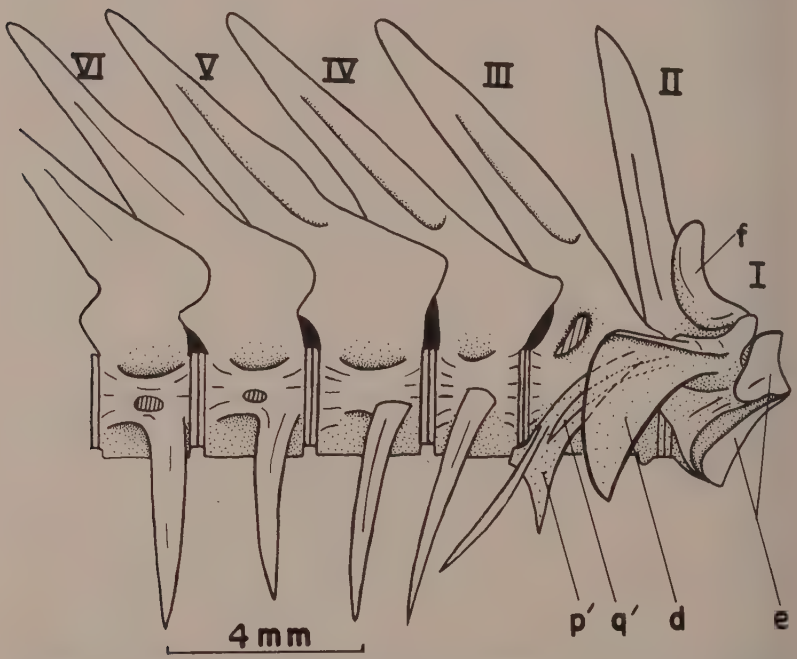

FIGURE 9. Lateral view of anterior vertebral column of the female *Ophidion holbrooki*. d: Winglike process of first vertebra. e: Facets articulating to occipital condyle. f: Dorsal aspect of winglike process forming neural arch. p′: Transverse process of third vertebra. q′: Rib of second vertebra.

Histological sections show that there is no opening on the terminal end of the bladder leading from the swim bladder lumen to the coelom.

The blood vessels which supply and drain the rete mirabile and the gas gland penetrate the middle of the ventral surface of the swim bladder at a point approximately half way between the anterior and posterior ends (Fig. 13). The blood vessels involved and the shape of the gas gland and the rete mirabile are the same as in the male.

Vertebral Column.—There are more differences than similarities between the vertebral column of the male and that of the female. The female also has a winglike process formed by a modification of the dorsal surface of the first vertebra (Figs. 9, 10A, 10B, 11, and 12). A neural arch (Figs. 9 and 10B), whose dorsal surface provides attachment for a muscle, M_2, (Figs. 11 and 12) is flattened as in the

male. The dorsal surface in the male is greater in anteroposterior width and is much more flattened horizontally than in the female. The remainder of the winglike process projects transversely but does not curve posteriorly as in the male. Only the transverse portion is present and it is narrow proximal to the vertebra and then distally widens dorsoventrally. The dorsal and ventral edges curve forward, making the anterior profile of the wings concave. Muscle M_3 attaches to the ventral surface of the winglike process (Figs. 11, 12, and 13). This muscle, as in the male, is divided into dorsal and ventral portions by Baudelot's ligament which connects the inner surface of the supracleithrum to the basioccipital region of the skull (Figs. 12 and 13). The winglike structure can also be easily removed as one piece from the first vertebra if the specimen is boiled.

The ribs of the third vertebra project from the dorsal surface of a transverse process formed on each lateral side of the centrum (Figs. 9, 10A, and 10B). The transverse process originates from approximately the same location as the ribs of other anterior vertebrae, but as

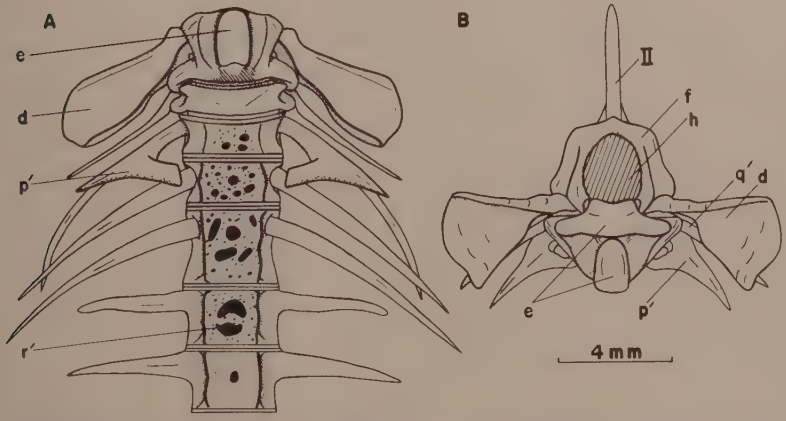

FIGURE 10. A. Ventral view of anterior section of vertebral column of the female *Ophidion holbrooki*. d: Winglike process of first vertebra. e: Facets articulating to occipital condyle. p′: Transverse process of third vertebra showing pitted area of ventral surface. r′: Pitted area of vertebra showing where swim bladder attaches. B. Anterior view of anterior section of vertebral column of the female *Ophidion holbrooki*. d: Winglike process of first vertebra. e: Facets articulating to occipital condyle. f: Dorsal aspect of winglike process forming neural arch. h: Passage for spinal cord. p′: Transverse process of third vertebra. q′: Rib of second vertebra.

it approaches a level with the fourth vertebra the inside portion of the distal half of the process contributes to the formation of a triangular bony process which swings inward toward the fourth vertebra, but terminates before reaching the latter. The ventral surface of the triangular process is pitted because it is strongly attached to the swim bladder (Figs. 11 and 12). The centra of the first six vertebrae are also pitted on their ventral surfaces, especially the third through the sixth vertebrae (Fig. 10A). This is also because the swim bladder is closely attached to this area and sends processes down into these pits to keep it strongly anchored, as can be seen when one tries to pry the swim bladder loose.

The anterior surface of the transverse process of the third vertebra attaches by a broad, strong ligament to the rib of the second vertebra. The latter rib in turn is attached by a wide ligament to the posterodorsal surface of the transverse portion of the winglike process of the first vertebra (Figs. 11 and 12). As mentioned in the description of the swim bladder, the ventral surface of this transverse portion is attached by a strong ligament to the swim bladder just behind the origin of the bulbous area located anteriorly. The outer extremity of the transverse portion of the winglike process is also connected to the cleithrum by a strong ligament on its ventral surface (Figs. 11 and 13).

Muscles.—In the female the muscular system is much the same as that of the male, but since there is no rocker and supporting mechanism in the female, some of the muscles are differently developed. One example is the muscle M_1. In the female this muscle (Figs. 11, 12, and 13) has no rocker to attach to and instead is connected by a very strong tendon to the dorsal surface of the swim bladder at a point just posterior to where the bulb-shaped area of the swim bladder arises and is also connected to the posterior portion of the ventral side of the winglike process. The winglike process is closely attached to the swim bladder by a wide ligament and at this point the tendon widens and attaches to both surfaces. Anteriorly the muscle attaches to the ventral and lower lateral section of the posterior half of the otic region of the skull. This muscle is by no means as large as in the male. The area of the otic region covered by the muscle is much smaller in the female and posteriorly the muscle narrows rather quickly to the point where it forms the tendon. This muscle is composed of striated fibers, can be clearly differentiated from the other musculature, and is more or less rounded.

As in the male, there is a thick muscle (M_2) which connects the

dorsal aspect of the winglike process and the epiotic area of the skull (Figs. 11 and 12). It is broadly attached to both structures, is composed of striated fibers, and in general appears the same in both sexes.

A third muscle (M_3) attaches broadly to the ventral surface of the portion of the wing projecting transversely. As in the male, the muscle passes forward to attach to the exoccipital region and the posterodorsal segment of the otic region (Figs. 11 and 13). There is a ridge above the foramina in this area which acts as a dorsal boundary for the muscle. One important difference exists between this muscle in the female and the corresponding one in the male. The innermost segment of the muscle attached to the wing continues posteriorly, but instead of attaching to a bone as in the male, it attaches to the swim bladder directly beneath the rib of the second vertebra. This particular rib is securely bound to the posterior edge of the winglike structure and to the anterior distal edge of the transverse process of the third vertebra

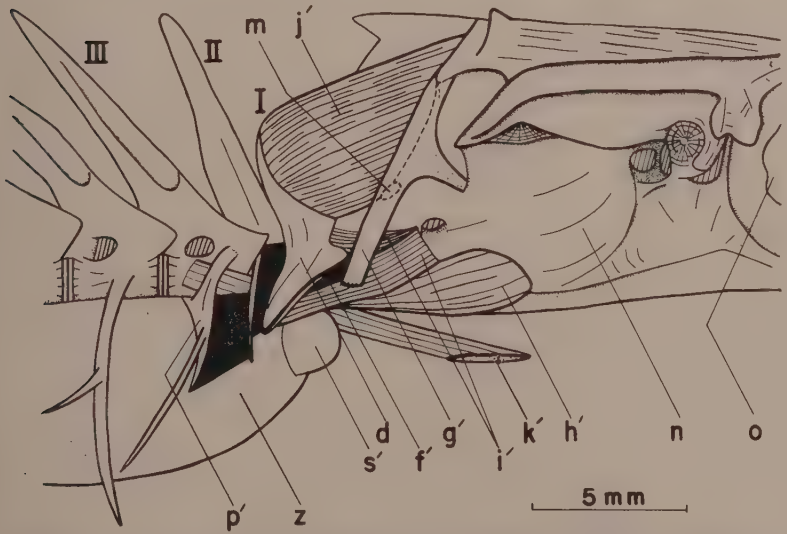

FIGURE 11. Lateral view of swim bladder and associated superficial musculature of the female *Ophidion holbrooki*. d: Winglike process of first vertebra. f′: Ligament connecting cleithrum and winglike process. g′: Supracleithrum (covering cleithrum). h′: Muscle M_1. i′: Muscle M_2. j′: Muscle M_3. k′: Pharyngeal retractor muscle. m: Foramina for branches of vagus nerve. n: Otic region. o: Orbit. p′: Transverse process of third vertebra. s′: Thick, hollowed bulbous areas of swim bladder. z: Swim bladder. Solid black areas here represent ligaments.

by means of wide, very strong ligaments (Figs. 11 and 12). As in all other muscles described, the fibers of this muscle are striated.

The pharyngeal retractor muscle in the female originates from the lateral side of the centrum of the third vertebra and from immediately below the origin of the modified rib of the vertebra (Figs. 12 and 13). In other respects it is exactly like the corresponding muscle in the male.

Associated Nervous System

The nerve supply for muscles M_1, M_2, and M_3 is from the vagus nerve in both sexes. There are two main foramina from which the nerves emerge to innervate the muscles, and these are indicated in the drawing of the skull (Figs. 4 and 5A). From the most dorsal foramen indicated, the branches of the vagus nerve emerge to supply the muscle M_2 which connects the dorsal surface of the winglike process and the epiotic area of the skull. The branches of the vagus innervating both muscles M_1 and M_3 exit from the second foramen, which is located ventrad and slightly posterior to the preceding foramen.

A nerve can be seen penetrating the external layer of the swim bladder along with the blood vessels which supply the rete mirabile. Attempts were made to trace the nerve, but because of its fragile nature this was not possible. It is assumed that this is a branch of the vagus nerve, the latter most commonly supplying the swim bladder of teleosts.

Functional Morphology

No live individual of *Ophidion holbrooki* has been observed by the author, so that the function of the swim bladder in the male and in the female can only be surmised. A description of what happens to the swim bladder and rocker in the male and to the bladder in the female when certain muscles are pulled in different directions is presented here.

In the male, it has been found that when muscle M_3 is pulled in an anterior direction, the entire winglike process is pulled forward. At the same time two ligaments attaching to the posterior end of the winglike process are stretched tautly. One attaches to the lateral wall of the supporting structure of the rocker while the other divides and attaches in two different places to the lateral face of the rocker (Figs. 6, 7, and 8). With this taking place on both sides of the rocker, a rigid transverse axis is formed. When muscle M_1, which attaches by a tendon to

the rocker at a position just dorsal and posterior to where the divided ligament attaches, is pulled in an anterior direction, the rocker rotates on the axis so that its dorsal portion revolves anteriorly and the ventral portion posteriorly. As a result, the aperture of the posterior face of the rocker is exposed in full to the lumen of the swim bladder. When the muscles are relaxed, the rocker and winglike structure return to their original positions as in a cam, reducing the exposure of the inside of the rocker to the lumen of the swim bladder.

In the female, as in the male, the muscle M_3 also pulls the winglike process of the first vertebra forward. Muscle M_3, which attaches to both the posteroventral surface of the winglike process and to the dorsal area of the swim bladder just behind the bulbous areas, when pulled in an anterior direction also pulls the swim bladder. When the muscle relaxes the bladder returns to its original position as does the winglike process. The ribs of the second and third vertebrae which attach to the bladder may act as stabilizers so that when the swim

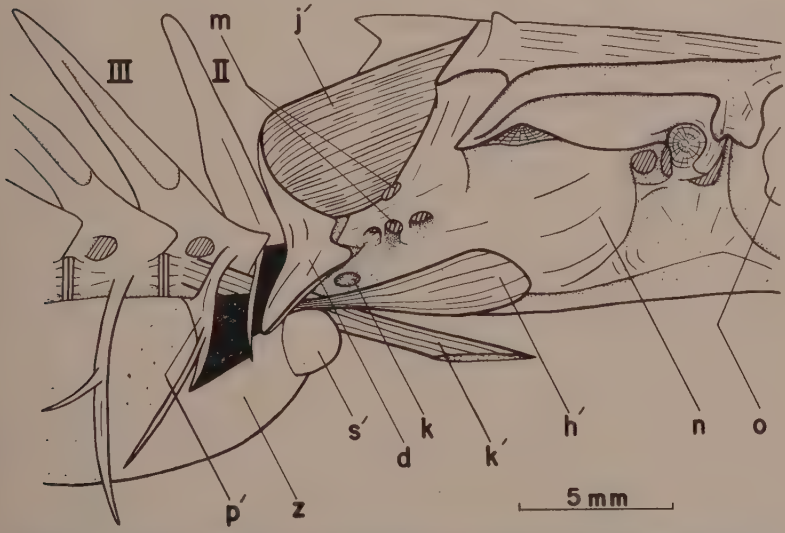

FIGURE 12. Lateral view of swim bladder and associated deep musculature of the female *Ophidion holbrooki*. d: Winglike process of first vertebra. h′: Muscle M_1. j′: Muscle M_2. k: Point of attachment for Baudelot's ligament. k′: Pharyngeal retractor muscle. m: Foramina for branches of vagus nerve. n: Otic region. o: Orbit. p′: Transverse process of third vertebra. s′: Thick, hollowed bulbous areas of swim bladder. z: Swim bladder. Solid black areas represent ligaments.

bladder is pulled forward it does not go too far in this direction and when the muscles relax the swim bladder returns to its original position quickly (Figs. 11, 12, and 13).

Muscle M_2 in both the male and the female may be an antagonistic muscle which prevents the fish jackknifing when muscles M_1 and M_3 contract.

Discussion

One interesting characteristic of the Family Ophidiidae is the sexual dimorphism which exists in some of its genera. An example of this is found in *Ophidion holbrooki* in which the vertebral column and swim bladder of the female and male differ markedly. A number of species of the genus *Otophidium* Gill, 1885, such as *"Otophidium" grayi,* show sexual dimorphism in the swim bladder. Here, as described by Briggs and Caldwell (1955: 288-as *O. omostigmum*), the female's swim bladder "is more or less heart-shaped from a ventral view" while in the male's swim bladder "a prominent posterior projection is developed. This protrusion is hollow and covered by a membrane at the distal end. Furthermore, this membrane is very elastic and presumably

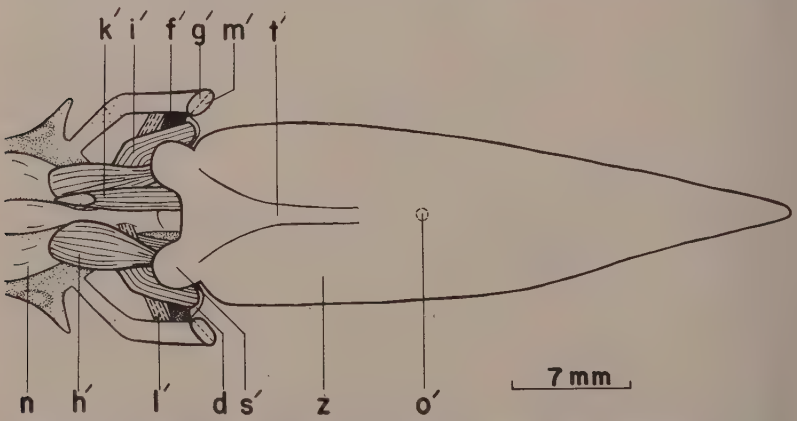

Figure 13. Ventral view of swim bladder and associated musculature of the female *Ophidion holbrooki*. d: Winglike process of first vertebra. f′: Ligament connecting cleithrum and winglike process. g′: Supracleithrum (covering cleithrum). h′: Muscle M_1. i′: Muscle M_3. k′: Pharyngeal retractor muscle. l′: Baudelot's ligament. m′: Cleithrum. n: Otic region. o′: Area of penetration of blood vessels supplying and draining rete mirabile and gas gland. s′: Thick, hollowed bulbous areas of swim bladder. t′: Thickened longitudinal ridge of swim bladder. z: Swim bladder.

can extend a considerable distance into the coelomic cavity when pressure is exerted upon the comparatively rigid air bladder." The purpose of this phenomenon is unknown and, until more is known of this family, one can only speculate.

The vertebral column of the male and the female of *O. holbrooki* differs in the number and types of modifications which exist. The winglike process in both sexes is essentially the same but for the part which extends posteriorly in the male. Other than this portion, the rest of the winglike process has approximately the same muscles (M_2 and M_3) attaching to it in the same locations. Also, the male has a large number of bony modifications for the support of the rocker, which the female lacks. In both male and female the third vertebra has a transverse process which plays a definite part in the swim bladder complex. In the male this forms the lateral walls of the supporting mechanism of the rocker while its posterior end is closely attached to the swim bladder. In the female it also attaches closely to the swim bladder. The extent of the modifications of the ventral surfaces of the vertebrae in the male are much greater than in the female. In the male they are needed to form the supporting mechanism of the rocker, whereas in the female which has no rocker the swim bladder attaches directly to the vertebral column.

The swim bladder itself is very similar in both sexes except for its anterior end. Also, muscle M_1 which attaches to the rocker in the male attaches directly to the swim bladder in the female. In the swim bladder of both sexes the bladder wall is composed of two layers and in the male a transparent area is former anteriorly, while in the female this does not take place. The rete mirabile and the gas gland in both sexes are supplied and drained by the same blood vessels as is true also for the dorsal area of the bladder. The posterior end of the swim bladder of both sexes has great elasticity and can be stretched for some distance.

The branches of the vagus nerve supplying similar muscles in the two sexes originate from the same foramina. Baudelot's ligament also has the same attachments and divides muscle M_3 into dorsal and ventral portions in both sexes.

Some attempt has been made to describe the functional morphology of the muscles associated with the swim bladder. In both sexes it is believed paired muscle M_2 acts as an antagonistic muscle to prevent the fish jackknifing when muscles M_1 and M_3 contract. Muscle M_3 in

both sexes may, on contraction, pull the winglike process forward. In the male, M_1 serves to rotate the rocker, but in the female it pulls the swim bladder forward. Until the composition of the rocker and the jellylike material surrounding it is known, it is difficult to predict whether the swim bladder and rocker in the male are used to produce sound.

One method of sound production in fishes is by the vibration of the swim-bladder wall. There are three main ways to accomplish this and they are described by Harden Jones and Marshall (1953). One way is to have one end of the external muscle attaching directly on the swim-bladder wall and the other end to a neighboring structure. This neighboring structure may be the skull, and Harden Jones and Nelson (1953) mention that this is found in *Ophidium (sic)* spp. as did Sorensen (1884). This type of sound production certainly fits the female of *Ophidion holbrooki* but until there is actual verification this can only be surmised.

The author has independently arrived at the same conclusions as Facciolá (1933) concerning the interaction of the rocker and the muscle M_1. Facciolá described how the rocker in *Ophidiom barbatum* changes its position when the two muscles (M_1) contract and then returns to its original status upon relaxation of the muscles. He also mentions (p. 164) ". . . a thin membrane lubricated by a mucus which favors the movement of the small bone," the small bone being the rocker, and "If pressure is exercised upon the anterior extremity, it undergoes a rotary movement on its longitudinal axis so that its convex superior surface becomes inferior. When pressure is relaxed it goes back to the original position without completing the other half round-trip." Facciolá also noticed that when pressure was exerted on the side of the fish a sudden noise was sometimes produced. The swim bladder of the male *Ophidion holbrooki* with its rocker mechanism may also be used to produce sound.

Summary

A description and comparison of the swim bladder, vertebral column, musculature, and associated structures in both sexes of *Ophidion holbrooki* (Putnam, 1874) are given. This species shows marked sexual dimorphism in these features. Particular attention is paid to the rocker and its supporting structure in the male. The possible interactions between the muscles, the swim bladder, the winglike process

of the first vertebra, and in the case of the male, the rocker, are described.

The possibility of sound production by the swim bladder existing in both sexes is discussed with reference to pertinent literature on related species.

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A PLEROCERCOID (CESTODA: TETRAPHYLLIDEA) FROM THE OAR-FISH, *REGALECUS GLESNE* (ASCANIUS), WITH NOTES ON THE BIOLOGY OF THE OAR-FISH

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ABSTRACT

A plerocercoid of the family Phyllobothriidae is reported and described from two specimens of the oar-fish. This larval cestode probably belongs to the genus *Phyllobothrium* Van Beneden, 1850. A possible cause for the occurrence of four specimens of the oar-fish along the lower west coast of Florida within a period of 60 hours is suggested.

INTRODUCTION

A tetraphyllidean plerocercoid larva of the family Phyllobothriidae Braun, 1900, was collected from the digestive tract of two specimens of the oar-fish, *Regalecus glesne* (Ascanius). The first of these two oar-fish was captured by Mr. William Kanitz at Treasure Island, St. Petersburg Beach, Florida, on 24 March 1960. Mr. Kanitz presented the fish to Dr. Victor G. Springer, ichthyologist, Florida State Board of Conservation Marine Laboratory, who kindly made the specimen available to me for parasitological examination. Although the fish was badly mutilated and dead at the time of my examination, six living specimens of a plerocercoid were obtained from the last two-thirds of the digestive tract. On 26 March 1960 a second oar-fish was caught with a small net in shallow water at Indian Rocks, Florida, by Mr. C. A. Henry Carlson, who presented the specimen to me for study. This fish was badly injured prior to capture, but it was still alive when I first saw it; however, the fish died before it could be returned to the Laboratory. It revealed five living specimens of the same species of plerocercoid found in the oar-fish first examined. The five plerocercoids were distributed as follows: one in the anterior one-third, three in the middle one-third, and one in the posterior one-third of the digestive tract. Examination of the gills, body musculature and internal organs of the two oar-fish did not reveal any helminth parasites. Two additional oar-fish recently captured along the lower west coast of Florida were not available to me for examination. One was caught in

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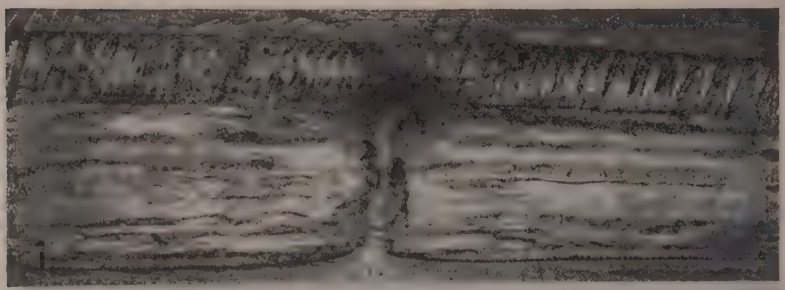

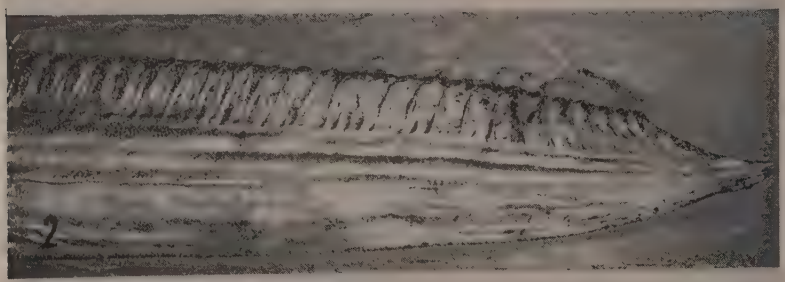

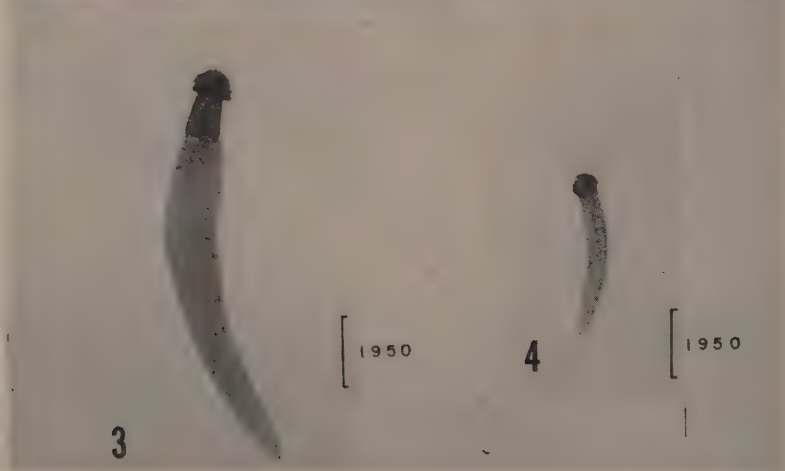

FIGURE 1. Photograph of oar-fish showing knife-like wound on posterior part of body.
FIGURE 2. Photograph of posterior end of body with vertebral column protruding.
FIGURES 3 AND 4. Photographs of tetraphyllidean plerocercoid of the family Phyllobothriidae.

the Gulf of Mexico on 25 March 1960 near Clearwater. The other was taken in the Gulf of Mexico near Charlotte Harbor on 26 March 1960.

The Parasite

The *pars antica* of the plerocercoid from the oar-fish bears near its anterior end four sessile bothridia, two on the dorsal side and two on the ventral side. At the apex of the scolex a myzorhynchus is present. A single accessory sucker is located on each bothridium as shown in Figure 5 and the bothridia are not divided into secondary areolae. A loop of the water-vascular system enters each bothridium with its general course parallel with the margin of the bothridium. Figures 3 and 4 are photographs of the largest and the smallest plerocercoids found in the digestive tract of the two specimens of *R. glesne* examined. Figure 5 is a free-hand drawing of the largest plerocercoid (Fig. 3) found. Measurements (in microns) of this specimen mounted in Canada balsam are as follows:

Pars antica scolecis	1950
Pars postica scolecis	9750
Pars bothridialis Pedunculus scolecis	780
Pars proliferens	1170
Myzorhynchus (length)	200
Myzorhynchus (width)	246
Accessory Sucker	190 x 190

This is the first record of a tetraphyllidean larva from the oar-fish. Similar larval forms have been reported from marine cephalopods and marine fishes (Dollfus, 1923a, 1923b, 1929, 1931; Euzet, 1956; Joyeux and Baer, 1936; Southwell, 1925; Wardle and McLeod, 1952). Most of these forms, many poorly described, have been placed in the genus *Phyllobothrium* and some have been described under the genera *Pelichnibothrium* and *"Scolex."* Under the name *Scolex pleuronectis* Mueller, 1788 (= *S. polymorphus* Rud., 1819, according to Southwell, 1925) a variety of larvae, all similar to each other, develop into a number of different species in the final host.

The plerocercoid from *Regalecus glesne* probably belongs to the genus *Phyllobothrium* Van Beneden, 1850. Although a complete tetraphyllidean life cycle has not been elucidated it appears on *a priori* grounds that the first stage of this larva occurs in a small crustacean and the adult is located in the gut of a selachian.

A Possible Cause for the Occurrence of the Oar-Fish

The unexpected appearance of the oar-fish from time to time is thought by many (Goode and Bean, 1895; Hardy, 1959; Norman, 1958; and others) to give credence to the legendary "sea-serpent" reports. Previous records of oar-fish in Florida coastal waters are few. Bullis and Arnold (1956) obtained an immature oar-fish (222.5 mm total length) approximately 90 miles south of Mobile, Alabama, at 29° 14′N, 87° 53′W Welsh (1920) reported a perfect 7-foot specimen stranded on March 20, 1920, on the beach at Long Key, Manatee County, Florida. Walters (1959) records an oar-fish being chased ashore by a shark on the east coast of Florida at Pompano Beach on 12 May 1958. Springer and Woodburn (1960) state: "During late June, 1954, a badly mutilated, but still living oarfish was found near shore at Clearwater Beach. The specimen, about seven feet long, was missing an estimated foot of its length. A plaster cast of the specimen, restored, is on display at the Sea-Orama on Clearwater Beach."

It is apparently unusual for oar-fish to come into shallow waters of the lower west coast of Florida and it is even more unusual when four specimens appear within a period of less than 60 hours. The following

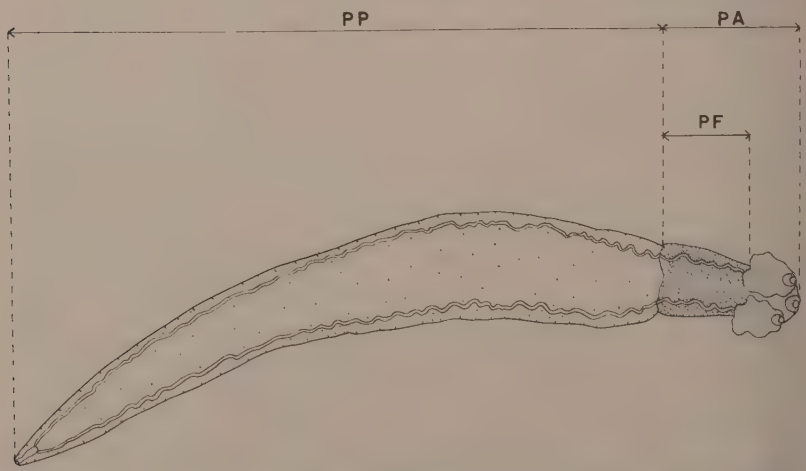

Figure 5. Free-hand sketch of tetraphyllidean plerocercoid of the family Phyllobothriidae.
PA—*Pars antica scolecis,* PF—*Pars postica scolecis,* PP—*Pars proliferens.*

information is included since it may give a clue to the sudden appearance of these four disabled oar-fish. Mr. B. Z. May, U. S. Fish and Wildlife Service, St. Petersburg Beach, Florida, (personal communication) reported discolored water and dead fishes on 23 March 1960 at approximately 30 to 35 miles west of Egmont Key, Florida. He also reported a count of 6,320,000 cells per liter of the dinoflagellate, *Gymnodinium breve* Davis, associated with the discolored water. Discolored water caused by concentration of *G. breve* is commonly known as Red Tide (see: Hutton, 1956). My experience with Red Tide has shown that, depending upon water temperature and other factors, fishes may be killed in Gulf of Mexico waters when the abundance of *G. breve* reaches a count of at least 250,000 cells per liter. In this connection, I have observed along the lower west coast of Florida discrete bodies of Red Tide water that are lethal to fishes. A fish that swims into such a body of water dies if it remains there, but if by chance the fish swims out of the unfavorable water, it may be affected only temporarily. Also, I have observed both birds and sharks feeding on distressed fishes at the edges of these discrete bodies of water. During the latter part of March 1960, sharks were common in Gulf of Mexico waters of the Tampa Bay area. Chief Pilot W. C. Wainright, Florida State Board of Conservation, has told me of his observation of a concentration of approximately 75 sharks from an airplane about 4 or 5 miles west of St. Petersburg Beach on 28 March 1960. Possibly, four oar-fish mentioned above entered Red Tide waters, became temporarily disabled, and were attacked by sharks.

Notes on the Biology of the Oar-Fish

The two specimens that I examined had knife-like wounds (Fig. 1) on the posterior parts of their body. The two other recently captured oar-fish which I did not examine were reported by the press to be similarly injured. Walters (1959) reports this type of injury to be common among all but the very young specimens. The oar-fish from Indian Rocks revealed that it had lost the posterior part of its body previously, and that, although the vertebral column was protruding (Fig. 2), the injury had healed. Jordan and Evermann (1898) give a range of from 275 to 400 in the ray count of the dorsal fin of the oar-fish. The damaged Indian Rocks specimen exhibited only 156 rays. The following measurements (in inches) were obtained from the Indian Rocks specimen:

Total length	78.5
Head length	6.5
Distance from tip of snout to eye	2.0
" " " " " (protruded) to eye	3.75
" " " " " to anus	45.5
" " " " " to insertion of pelvic fin	7.25
Body depth:	
Greatest (midway between tip of snout and anus)	7.0
Through center of eye	5.75
At anus	6.25
Distance from anus to body injury	9.5

The oar-fish captured at Treasure Island was so badly mutilated that accurate measurements of the fish were impossible.

Concerning the taxonomy of the oar-fish Goode and Bean (1895) state: "It is not certain that there is more than one species of *Regalecus,* although, as the synonymy . . . clearly shows, various names have been suggested in connection with the comparatively few individuals which, during the past century and a half, have been captured in the North Atlantic. . . . It should also be said that most of the individuals studied have been in very imperfect condition, and also that in many instances the observations have been made by untrained observers, so that it seems doubtful whether there is really more than one species to be assigned to the Atlantic fauna. At all events, Günther, Collett, Lütken, and Day agree in the idea that it is impossible to discriminate between the forms already described, and we follow their lead in considering them all, for the present, as a single species . . ." Although some modern-day ichthyologists believe there is good evidence that there are three or four species of *Regalecus,* this view is still not generally accepted and I choose to identify the forms I have seen from the west coast of Florida as *R. glesne*. However, the possibility of individual variation in the external markings, color, and other characters appears to be great. The specimens I examined had larger blotches and more numerous dark streaks, most numerous anteriorly, as compared with specimens figured by others (Goode and Bean, 1895; Hardy, 1959; Norman, 1958; and Norman and Fraser, 1949). These blotches and streaks had a definite pattern; the pupil of the eye was elongate. Both of these features are illustrated in Figure 6. In the

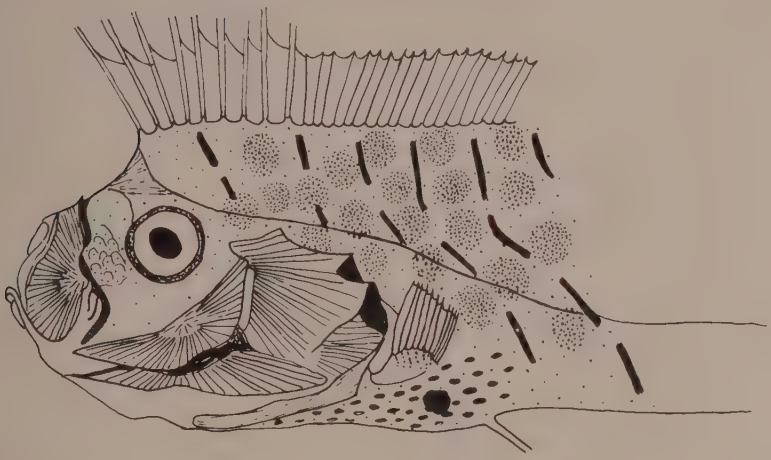

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FIGURE 6. Free-hand sketch of the head and the anterior part of the body of the oar-fish showing the characteristic large blotches and dark streaks and the ellipsoidal pupil of the eye. (Only part of the dorsal and pelvic fins are shown.)

Indian Rocks specimen the longer axis of the eye measured 16 mm and the shorter axis 13 mm. Bullis and Arnold (1950), reporting on the capture of an immature oar-fish from the Gulf of Mexico, stated: "The body surface was covered with a silvery 'guanin,' which rubbed off at the slightest touch. . . ." This was also true of both specimens I examined. The oar-fish appears to be a filter-feeder. This is evidenced by the well-developed gill-rakers and the relatively short, straight digestive tract with no evidence of a stomach in either of the dissected specimens. The total length of the digestive tract of the Indian Rocks specimen measured 40 inches.

Norman and Fraser (1949), referring to the oar-fish, state: "The flesh is quite useless as food, and it is recorded that in Scandinavia even dogs refused to eat it, whether offered raw or cooked." In this connection, an unfrozen piece of the oar-fish which was caught at Indian Rocks was offered to a dog who normally eats fish. The dog refused to eat the uncooked fish, but the fish was readily accepted after it was fried. Six persons, without knowing the type of fish being eaten, volunteered to taste the fried oar-fish. One biologist remarked

that it tasted like "pompano." The consensus was that the taste was suitable but that the fish was objectionable because it was extremely flaccid. Prolonged frying did not remove the flaccidity.

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FLORIDA STRAITS TRANSPORTS: JULY 1958 - MARCH 1959

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Figures for transports of water through the Florida Straits, as determined from voltage-difference readings made between Havana and Key West from August, 1952 to May, 1956 and from June, 1956 to July, 1958 were reported in Bull. Mar. Sci. Gulf and Carib., 7 (3): 252-254 and 9 (2): 222-223 respectively.

Arrangements have been made with the Marine Laboratory in Miami for a continuation of the program of the measurements, in the hope that by virtue of propinquity they will be able to keep more closely informed of the condition and calibration of the recording apparatus than I have been able to do. Accordingly I present, in Table I, the concluding readings made at the Woods Hole Oceanographic Institution.

TABLE 1

24-HOUR AVERAGES OF FLORIDA STRAITS TRANSPORTS IN MILLIONS OF CUBIC METERS PER SECOND.

1958					
July	5	41.2	Nov.	2	36.4
	6	42.6		8	37.8
	19	49.6		9	39.6
	20	54.2		16	40.1
	26	46.3		22	39.7
Aug.	3	46.7		23	39.6
	9	50.1		29	41.6
	10	49.9		30	38.8
	16	49.8	Dec.	6	41.0
Sept.	7	49.5		7	42.6
	20	42.5		13	32.3
	21	44.3		14	36.6
	27	44.9		20	36.0
	28	47.3		21	37.4
Oct.	4	43.0		27	38.9
	5	43.9		28	39.4
	11	37.3	1959		
	12	39.0	Jan.	18	28.5
	18	38.0		31	33.7
	19	37.7	Feb.	1	32.8
	26	34.1	Mar.	21	32.2
				22	34.5

THE OCCURRENCE OF *STEPHANOSCYPHUS CORNIFORMIS* KOMAI (SCYPHOZOA) IN THE WESTERN ATLANTIC

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ABSTRACT

The range of the scyphozoan polyp *Stephanoscyphus corniformis* Komai is extended to include the western Atlantic. Records are given for the Gulf of Mexico, and its possible affinities with the medusoid genus *Linuche* are discussed.

The odd little scyphozoan polyps of the genus *Stephanoscyphus* are rather common organisms, attached to rocks, old shells, and other hard objects. Three or four species form branched colonies, but at least two others are simple and have solitary habits. One of the solitary species, *S. simplex* Kirkpatrick, is reported by Kramp (1959) to have a depth range of 430 to 7000 m, but the other species, *S. corniformis* Komai, is found in shallow water from 10 to 94 m. Kramp (1959) believes the distribution of *corniformis* to be circum-global, but published records for the Atlantic are known for only two localities in the Gulf of Guinea off the west coast of Africa. There are several records for the western Pacific and one from the west coast of South America. In view of the present published distribution of *S. corniformis,* attention should be called to the widespread distribution of this species in the tropical western Atlantic.

Stephanoscyphus corniformis is a common animal, and the complete lack of records for its presence in the western Atlantic is rather puzzling. However, the small size and lack of conspicuous structures of this species are probably responsible to some extent for this lack of information.

The most distinctive feature of *Stephanoscyphus corniformis* is a slender chitinous tube, usually less than 15 mm long. It is attached by a small pedal disk. The tube is very small above the attachment disk, but expands gradually and evenly to the circular aperture. At the top it is about 2 mm in diameter for a 15 mm specimen. The tube is usually curved, and is rather closely annulated. It is quite inconspicuous, being nondescript brown in color, and is easily overlooked.

The writer has observed this species over a period of more than ten

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years, but did not keep records until recently. However, material on hand at the Gulf Coast Research Laboratory shows that *S. corniformis* is widespread in shallow water throughout the Gulf of Mexico. Caribbean material is not on hand, but a coral collected by the U. S. Fish and wildlife M/V OREGON (station number lost) from the northern coast of Brazil has several specimens attached to it. Gulf of Mexico records are as follows:

28°N, 83°10′W, 10 fathoms. Seven small specimens attached to a coral, *Manicina mayori* Wells. Collected in July, 1947 by Donald R. Moore and Gilbert Voss.

29°17′N, 88°16′W, 46 fathoms. Several specimens attached to dead coral. Collected March 26, 1958, by the U. S. Fish and Wildlife M/V SILVER BAY.

South of Cameron, Louisiana, in about 30 fathoms, 1957.

20°02′N, 19°58′W, 26 fathoms. Numerous examples on rocks collected January 28, 1959, by the M/V SILVER BAY.

20°02′N, 91°51′W, 27 fathoms. Numerous examples on rocks collected March 2, 1959, by the M/V SILVER BAY.

The medusae are very poorly known, but apparently the medusa of *S. mirabilis* Allman, a species found growing within sponges, is *Nausithoë,* Order Coronatae. The medusa of *S. corniformis* is not small ephyrae in *S. simplex* that appear in all respects to be young *Nausithoë,* Oorder Coronatae. The medusa of *S. corniformis* is not known, but is presumably very similar. The possibility exists that it is the scyphistoma of *Linuche,* a shallow warm water genus very similar to *Nausithoë*. *Linuche unguiculata* Eschscholtz is a common West Indian species which presumably arises from a scyphistoma. A closely related species, *L. aquila* Haeckel, is widely distributed over the tropical Pacific. If it is *Linuche,* then *S. corniformis* is the scyphistoma of two different species of medusae, but can be distinguished only in the sexual stage. However, until proof of relationship can be established, it is best to leave this scyphistoma in the genus and species established for it.

This report is the first record of *Stephanoscyphus* in the Gulf of Mexico and the first record of *S. corniformis* in the western Atlantic. This species appears to have a world wide distribution in warm seas as previously suggested by Kramp (1959).

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